US Army Corps of Engineers

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-CO-3

CASE HISTORIES OF CORPS BREAKWATER AND JETTY STRUCTURES

Report 7
NEW ENGLAND DIVISION

by

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January 1989
Report 7 of a Series

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32278 and Work Unit 31269

The following two letters used as part of the number designating technical reports of research published under the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program identify the problem area under which the report was prepared:

	Problem Area		Problem Area
CS	Concrete and Steel Structures	EM	Electrical and Mechanical
GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

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COVER PHOTOS:

TOP — Field Research Facility, Duck, North Carolina.

BOTTOM — View of jetties at the mouth of Kennebunk River, Kennebunk, Maine.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report REMR-CO-3	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES, Coastal Engineering Research Center 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39181-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION US Army Corps of Engineers 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. See reverse

11. TITLE (Include Security Classification)

Case Histories of Corps Breakwater and Jetty Structures; Report 7: New England Division

12. PERSONAL AUTHOR(S)
Sargent, Francis E.; Bottin, Robert R., Jr.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Report 7 of a Series	FROM Oct 86 TO Apr 87	January 1989	110

16. SUPPLEMENTARY NOTATION
A report of the Coastal Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	Breakwater	REMR (Repair, Evaluation,
			Concrete Armor Units	Maintenance, and Rehabilitation)
			Jetty	Rubble-mound structures

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is seventh in a series of case histories of US Army Corps of Engineers (Corps) breakwater and jetty structures at nine Corps divisions. Chronological histories are presented for 52 projects located along the New England coastline and managed by US Army Engineer Division, New England (NED). Presently, NED is responsible for 37 jetties and 46 breakwaters which have a cumulative length of 154,185 ft and are almost entirely of stone construction. Localized damage from wave attack appears to be the major cause of structural deterioration. A total of 36 projects has had structural modifications and/or repairs since original construction. Almost all the repairs have consisted of placing new stone on the structures.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

10. SOURCE OF FUNDING NUMBERS (Continued).
Work Unit 32278 and Work Unit 31269.

PREFACE

This report was prepared as part of the Coastal Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was carried out jointly under Work Unit 32278, "Rehabilitation of Rubble-Mound Structure Toes," of the REMR Program and Work Unit 31269, "Stability of Breakwaters," of the Civil Works Coastal Area Program. For the REMR Program, Coastal Problem Area Monitor is Mr. John H. Lockhart, Jr., Office, Chief of Engineers (OCE), US Army Corps of Engineers (Corps). REMR Program Manager is Mr. William F. McCleese of the US Army Engineer Waterways Experiment Station's (WES's) Structures Laboratory, and Coastal Problem Area Leader is Mr. D. D. Davidson of WES's Coastal Engineering Research Center (CERC). Messrs. John G. Housley and Lockhart, OCE, are Technical Monitors of the Civil Works Coastal Area Program.

This report is seventh in a series of case histories of Corps breakwater and jetty structures at nine Corps divisions. The case histories were written from information obtained from several sources (where available) which included inspection reports, conferences, telephone conversations, project plans and specifications, project files and correspondence, design memoranda, literature reviews, model studies, surveys (bathymetric and topographic), survey reports, annual reports to the Chief of Engineers, House and Senate documents, and general and aerial photography. Unless otherwise noted, any changes to the prototype structures subsequent to October 1985 are not included.

This work was conducted at WES during the period October 1986 to April 1987 under general direction of Dr. James R. Houston and Mr. Charles C. Calhoun, Chief and Assistant Chief, CERC, respectively; and under direct supervision of Mr. C. E. Chatham, Jr., Chief, Wave Dynamics Division (CW), and Mr. D. D. Davidson, Chief, Wave Research Branch. This report was prepared by Messrs. Francis E. Sargent and Robert R. Bottin, Jr., Wave Processes Branch, CW, CERC, and it was edited by Ms. Shirley A. J. Hanshaw, Information Products Division, Information Technology Laboratory, WES.

Commander and Director of WES during publication of this report was COL Dwayne G. Lee, EN. Technical Director was Dr. Robert W. Whalin.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To obtain
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
tons (2,000 lb, force)	8806.443353	newtons

CASE HISTORIES OF CORPS BREAKWATER AND JETTY STRUCTURES
NEW ENGLAND DIVISION

INTRODUCTION

Background

1. The US Army Corps of Engineers (Corps) is responsible for a wide variety of coastal structures located on the Atlantic, Pacific, and gulf coasts, the Great Lakes, the Hawaiian Islands, other islands, and inland waterways. Coastal improvements such as breakwaters or jetties are necessary to provide harbor protection and the safe passage of vessels. These structures are subjected continuously to wave and current forces and usually are constructed on top of movable-bed materials. Under these conditions structural deterioration may occur and, at some point, maintenance, repair, or rehabilitation may be required when the structure deteriorates and/or fails to serve the existing needs of the project. Some of these projects have been maintained for 150 years or more. Methods of construction and repair have varied significantly during this time, due principally to a better understanding of coastal processes, availability of construction materials, existing wave climates, regional construction practices, and economic considerations.

Purpose

2. The purposes of this report are to provide insight into the scope, magnitude, and history of coastal breakwaters and jetties under Corps jurisdiction; determine their maintenance and repair history; determine their methods of construction; and make this information available to Corps personnel. To accomplish these objectives, case histories of Corps breakwater and jetty structures have been developed to quantify past and present problem areas (if any), to take steps to rectify these problems, and to subsequently evaluate the remedial measures. General design guidance can be obtained from the solutions that have been most successful. Information in this report should be of particular value to the Corps personnel in the US Army Engineer Division, New England (NED), and possibly to non-Corps personnel. Further

research is being conducted to address problems where adequate solutions are lacking or where specific guidance is required (i.e. general armor stability, toe protection, localized damage, use of dissimilar armor, and wave runup and overtopping).

PART II: SUMMARY OF CORPS BREAKWATER AND JETTY PROJECTS IN NED

3. NED is presently responsible for 37 jetties and 46 breakwaters which are principal or partial features of 52 projects. All of the projects are located on or near the Atlantic coastline from northern Maine to western Connecticut (Figure 1). There is a total of 154,185 lin ft* of breakwater (62.4 percent) and jetty (37.6 percent) structures which are almost entirely (99.7 percent) of stone construction. With the exception of a few projects which were originally constructed using regularly shaped stone blocks, the rubble-mound structures have been built using various sizes of stone. Use of concrete as a building material has been limited to 2 or 3 projects and has not been used in the past 35 years. Steel sheet piles were used in construction of one breakwater (Eastport Harbor).

4. The cross sections of many structures are constructed with steeper channel or harbor-side slopes than sea-side slopes. The largest cover stones are typically placed in a single row on the crown, and the core is usually made up of smaller "quarry run" stone. Most of the structures have been built without blanket or apron stone. Typical crown elevations are from +5 to +26 ft mean low water (mlw). The large variation in crown elevations is mainly due to local tide levels, which vary in the mean from 2 to 18 ft. Relative to mean high water (mhw), crown elevations are typically +2 to +8 ft. Crown widths on structures with one stone crown width are typically 4 to 8 ft, while the variation in crown width for all structures is usually from 2 to 20 ft. Side slopes are typically 1V:1H on the channel or harbor side and 1V:1.5H on the sea or ocean side. Side slopes on the newer structures are typically 1V:1.5H on both sides. Repaired side slopes are usually from 1V:1.5H to 1V:2H. Cover stone, usually placed to a relative thickness of 1 or 2 layers, varies from a minimum of 0.25 ton in low wave climate environments to a maximum of 15+ tons (Point Judith). The newest projects (Plymouth and Provincetown Harbors breakwaters and Andrews River west jetty) were all completed in the early 1970's.

5. Sufficient quantitative information on long- or short-term structural deterioration due to various wave climates was not found. Periodic

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

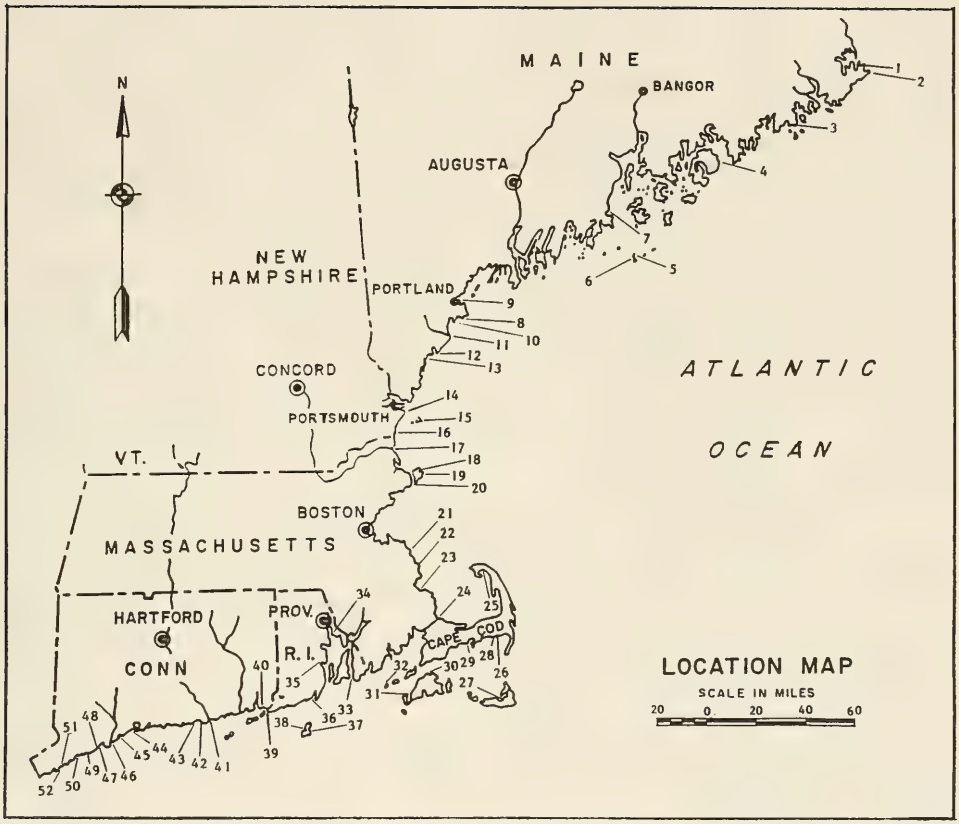


Figure 1. Location of projects with breakwater or jetty structures maintained by NED (Numbers refer to table number in text)

visual surveys, taken between 1960 and 1980, are qualitative and subjective, both in time and between inspections. Repairs to the structures typically involved adding new armor stone to damaged sections, usually returning the structure to the original design geometry or to the existing geometry of surrounding undamaged sections. Repairs or modifications, which include adding a structure or lengthening an existing structure, have been made at 36 of the 52 projects. Of the 30 projects which have had structures repaired, several of these could also be considered modified in terms of changes in stone sizes, geometry, or shortening of a structure from its original or previously repaired condition. Where repairs have been fairly frequent, flatter side slopes and/or larger stone sizes have been used to increase the structural stability. Localized damage and subsequent unraveling appear to be the major problem areas concerning NED structures. Several structures have had their landward ends sand tightened with additional stone placed along their seaward side slopes. The following projects best illustrate repair histories of structures within NED: Saco River, Kennebunk River, Isles of Shoals, Hampton Harbor, Newburyport Harbor, Rockport Harbor, Gloucester Harbor, Green Harbor, Cape Cod Canal, Nantucket Harbor, Hyannis Harbor, Sakonnet Harbor, Point Judith, and Block Island.

6. None of the structures have been model tested for stone slope stability. Hudson's equation and depth- or fetch-limited wave heights are used in selecting armor stone sizes. Case histories of the project structures are included in Tables 1-52. Pertinent summary information on each project is presented in the following listing:

Location	Table	Project Type & No.*	Armor Type**	Length	Date of Origin	Improvement†
Eastport Harbor, Maine	1	B(1)	SSP	485	1961	N
Lubec Channel, Maine	2	B(2)	S	725	1884, 1956	N
Moosabec Bar, Maine	3	B(1)	S	400	1891	N

(Continued)

* Indicates type and number of structures: B-breakwater (B(1) indicates one breakwater), J-jetty.

** Indicates armor type: S-stone armor, C-concrete sheet pile or wall, SSP-steel sheet pile, B-stone blocks.

† N-none (no repairs or modifications since construction), R-repair, M-modification.

Location	Table	Project Type & No.*	Armor Type**	Length	Date of Origin	Improvement†
Bar Harbor, Maine	4	B(1)	S	2,510	1888	N
Matinicus Island, Maine	5	B(1)	S	450	1911	R
Criehaven Harbor, Maine	6	B(1)	S	300	1935	R
Rockland Harbor, Maine	7	B(1)	S	4,346	1881	R
Richmond Island Harbor, Maine	8	B(1)	S	2,000	1881	N
Portland, Maine	9	B(2)	S	2,900	1836, 1950	N
Scarboro River, Maine	10	J(1)	S	800	1962	N
Saco River, Maine	11	J(2)	S	11,400	1873	R,M
Kennebunk River, Maine	12	J(2)	S,B,C	1,124	1829	R,M
Wells Harbor, Maine	13	J(2)	S	4,225	1961	M
Little Harbor, N.H.	14	B(2)	S	1,450	1894	R
Isles of Shoals, Maine and N.H.	15	B(3)	S	1,450	1821, 1913	R
Hampton Harbor, N.H.	16	J(2)	S	3,300	1933	R,M
Newburyport Harbor, Mass.	17	J(2)	S	6,563	1881	R
Sandy Bay, Mass.	18	B(1)	S,B	6,100	1886	N
Rockport Harbor, Mass.	19	B(2)	S	1,100	1836	R
Gloucester Harbor, Mass.	20	B(1)	S,B	2,250	1894	R
Scituate Harbor, Mass.	21	B2(2)	S	1,470	1881	R,M
Green Harbor, Mass.	22	J(2)	S	1,495	1898	R,M
Plymouth Harbor, Mass.	23	B(1)	S	3,500	1968	N
Cape Cod Canal, Mass.	24	J(2)	S	3,690	1908	R
Provincetown Harbor, Mass.	25	B(1)	S	2,500	1970	N
Chatham Harbor, Mass.	26	J(1)	S	500	1965	M

(Continued)

Location	Table	Project Type & No.*	Armor Type**	Length	Date of Origin	Improvement†
Nantucket Harbor, Mass.	27	J(2)	S	11,942	1881	R
Andrews River, Mass.	28	J(2)	S	1,255	1967, 1973	N
Hyannis Harbor, Mass.	29	B(1)	S,B	1,170	1827	R
Lagoon Pond, Mass.	30	J(1)	S,B	650	1935	M
Menemsha Creek, Mass.	31	J(2)	S	685	1945	R
Cuttyhunk Harbor, Mass.	32	J(2)	S	800	1906	R
Sakonnet Harbor, R.I.	33	B(1)	S	800	1836	R,M
Bullocks Point Cove, R.I.	34	J(1)	S	300	1958	N
Wickford Harbor, R.I.	35	B(2)	S	1,955	1949	N
Point Judith, R.I.	36	B(3)	S	12,850	1891, 1911	R
Block Island, R.I.	37	B(2)	S	3,050	1870	R
Great Salt Pond, R.I.	38	J(1)	S	1,690	1896	R
Watch Hill Cove, R.I.	39	J(1)	S	400	1948	N
Stonington Harbor, Conn.	40	B(2)	S	4,925	1875	R
Saybrook, Conn.	41	J(2)	S	4,550	1873	R
Duck Island Harbor, Conn.	42	B(3)	S	7,547	1891	R
Patchogue River, Conn.	43	J(1)	S	600	1956	N
New Haven Harbor, Conn.	44	B(3)	S	12,150	1880	R
Milford Harbor, Conn.	45	J(2)	S	860	1875	R
Housatonic River, Conn.	46	B(1)	S	5,820	1889	R
Bridgeport Harbor, Conn.	47	B(2)	S	5,933	1871, 1908	R
Fairfield, Conn.	48	J(1)	S	800	1951	N
Southport Harbor, Conn.	49	B(1)	S,B,C	1,320	1838	R
Saugatuck River, Conn.	50	B(1)	S	600	1896	N
Cove Island, Conn.	51	J(1)	S	400	1958	N
Stamford Harbor, Conn.	52	B(2)	S	4,100	1941	N

Table 1

Eastport Harbor Breakwater

Eastport Harbor, Maine

Date(s)	Construction and Rehabilitation History
1961-1962	A 485-ft-long steel sheet-pile breakwater was constructed (Figure 2). The L-shaped breakwater consisted of a double row of sheet piles, spaced 40 and 50 ft apart on the 95- and 390-ft legs, respectively, and were filled with stone pieces weighing 1,000 lb or less. The top of the structure was at +26 ft mean low tide (mlt), and the mean tide range was 18.2 ft. Stone pieces, weighing less than 200 lb each, were placed in an apron along the breakwater's exposed toe. The approximate cost of the breakwater was $450,000.
1974	Visual inspections up to this time indicated that the breakwater was in good condition.
1986	The present condition of the breakwater is not known. The Federal breakwater has been deauthorized and is no longer subject to Federal maintenance.

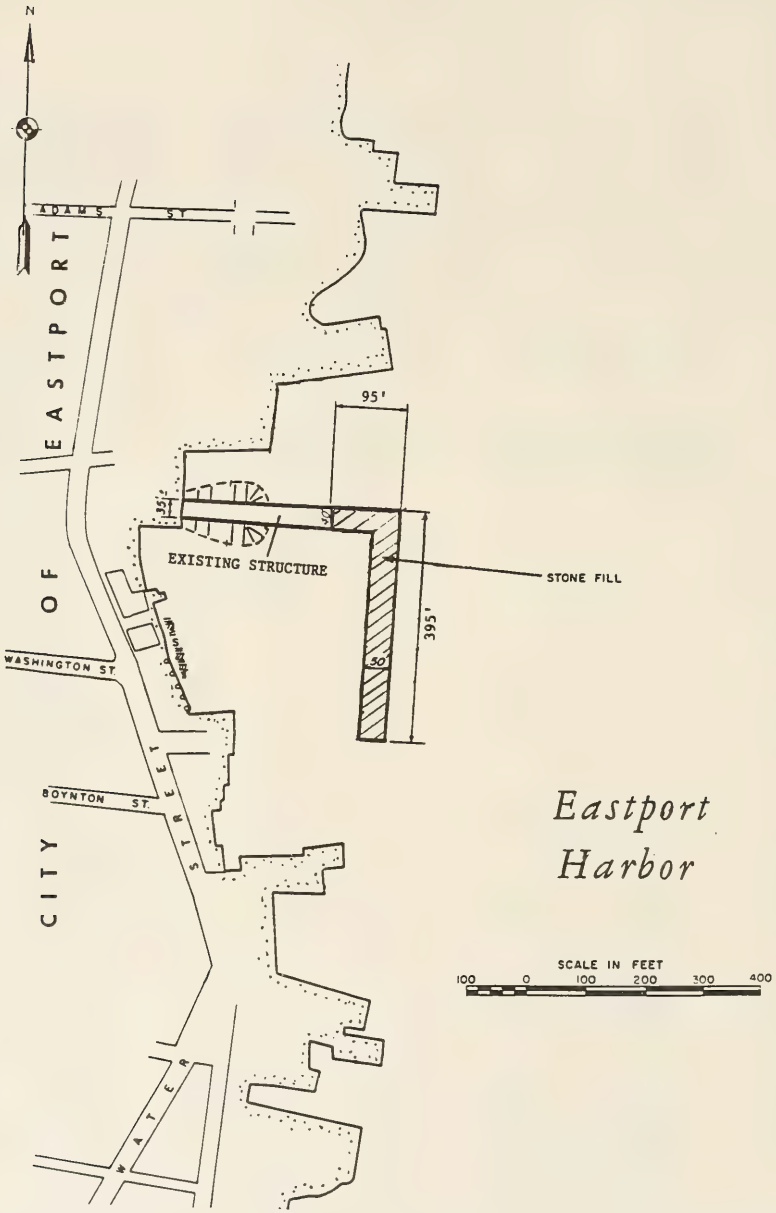


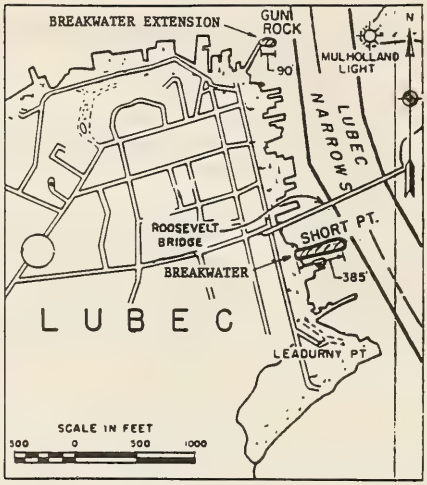
Figure 2. Plan view of steel sheet-pile breakwater at Eastport, Maine

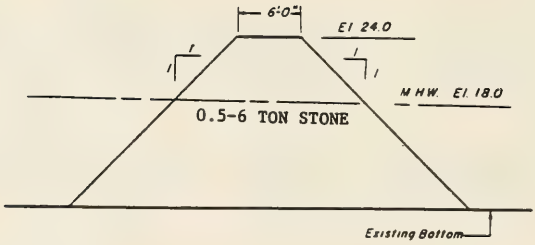
Table 2

Gun Rock and Short Point Breakwaters

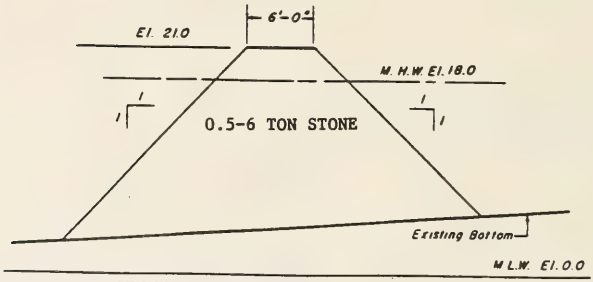
Lubec Channel, Maine

Date(s)	Construction and Rehabilitation History
1884	Gun Rock breakwater (Figure 3) was constructed to a length of approximately 250 ft.
1956	The Gun Rock breakwater was extended 90 ft seaward, and the 385-ft Short Point breakwater was constructed. The breakwaters were built with a 6-ft crown width and 1V:1H side slopes using 0.5- to 6-ton stones. The smaller stone sizes were used as core stone. Design crown elevations were +21 and +24 ft mlw at Gun Rock and Short Point, respectively. Total cost was $63,000 for placing 7,500 tons of stone (approximate figures).
1967	The breakwaters were inspected and considered to be in good condition. Because of an adjacent bridge abutment, the Short Point breakwater no longer serves a useful purpose, and no reason for future maintenance exists.
1974	The Gun Rock breakwater was visually inspected and considered to be in good condition.
1981	Visual inspection of Gun Rock breakwater indicated it was in good condition.
1984	The Gun Rock breakwater was visually inspected and considered to be in good condition.





SECTION OF BREAKWATER
AT SHORT POINT



SECTION OF BREAKWATER EXTENSION
AT GUN ROCK

Figure 3. Plan view and design cross sections of breakwaters at Lubec Channel, Maine

Table 3

Moosabec Bar Breakwater

Moosabec Bar, Maine

Date(s)	Construction and Rehabilitation History
1891 1892	As part of channel improvements, a 400-ft-long rubble-mound breakwater was constructed (Figure 4).
1962- 1977	Inspections of the breakwater indicated several small breaks along the top, but its overall condition was considered fair to good.
1986	The structure has no known repair history.

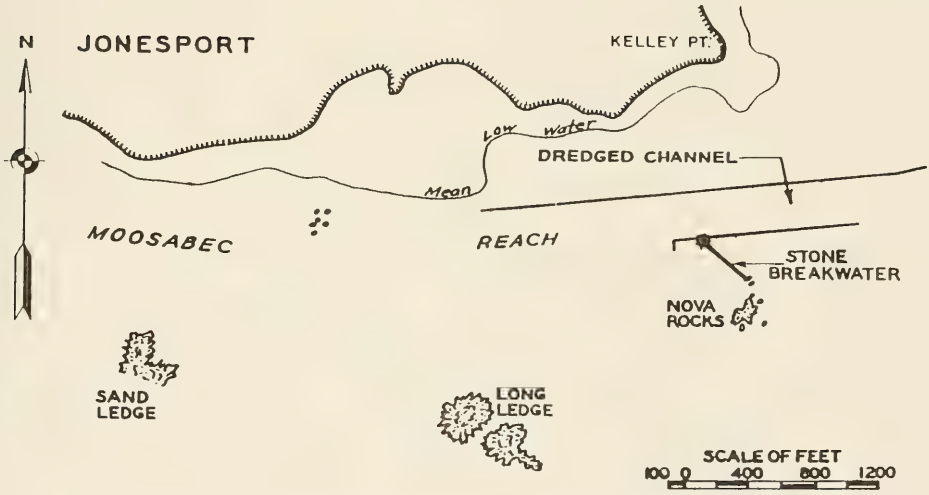


Figure 4. Plan view of breakwater at Moosabec Bar, Maine

Table 4

Bar Harbor Breakwater

Bar Harbor, Maine

Date(s)	Construction and Rehabilitation History
1888-1917	A 2,510-ft-long breakwater was constructed providing protection to the wharves and Anchorage area at Bar Harbor (Figure 5). By 1917 the breakwater was 88 percent complete being built to its full length but not its full section (Figure 5, inset). Remaining work consisted of placing final top stone over a section of the structure. This portion of the project is inactive. The design section had 1V:1H side slopes, a 20-ft top width, and a +10.4 ft mlw top elevation. A total of 382,000 tons of stone was placed at a cost of $385,000.
1961-1977	Inspections indicated the breakwater to be in fair to good condition.
1986	The structure has no known repair history.

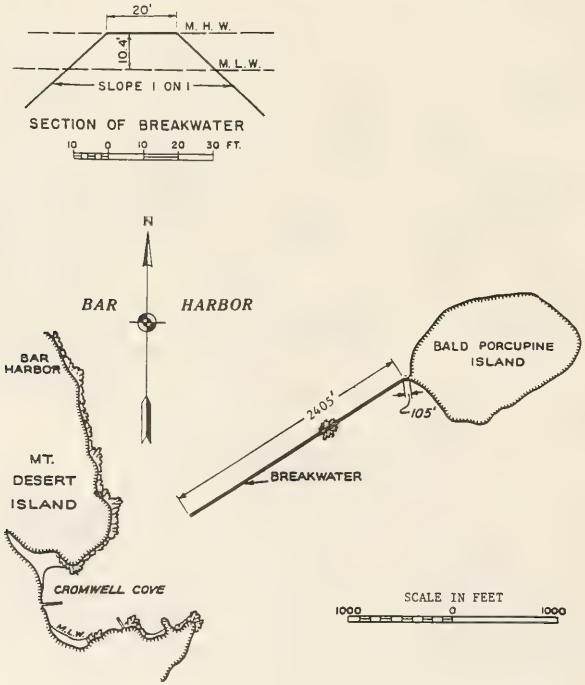


Figure 5. Plan view and typical section of breakwater at Bar Harbor, Maine

Table 5

Matinicus Harbor Breakwater

Matinicus Island, Maine

Date(s)	Construction and Rehabilitation History
1911	A 450-ft-long rubble-mound breakwater was constructed (Figure 6) using 9,080 tons of stone for a total cost of $11,800.
1934	Repairs were made to the structure. Details of the work are not known.
1961-1962	The breakwater was rehabilitated using 5,930 tons of stone at a cost of $103,000. The repair geometry (Figure 6, inset) had 1V:1.5H side slopes, a 10-ft top width, and a +18 ft mlw crown elevation. Seventy-five percent of the stone by weight was a minimum of 10 tons, and the remainder was a minimum of 3 tons. The cover stones weighed a minimum of 10 tons.
1967-1977	Inspections indicated the breakwater was in good condition with some displacement of cover stone on its seaward face.

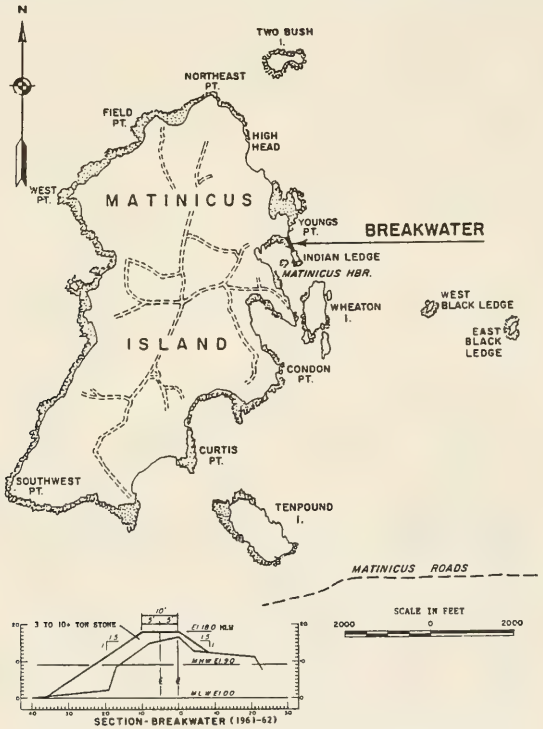


Figure 6. Location may of breakwater at Matinicus Harbor, Maine

Table 6

Criehaven Harbor Breakwater

Ragged Island, Maine

Date(s)	Construction and Rehabilitation History
1935	A 300-ft-long rubble-mound breakwater was constructed (Figure 7) using 8,700 tons of stone at a cost of $40,800. The structure was built to an elevation of +15 ft mlw, a 10-ft top width, and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively (Figure 7, inset). The mean tide range is 9.1 ft.
1938	The breakwater was repaired using 1,600 tons of stone at a cost of $7,950.
1960-1977	Various inspections indicated the breakwater was in fair to good condition with some slippage of stone noted.
1982	A condition survey was made of the breakwater cross sections, and a center-line profile was obtained (no details).
1986	The breakwater has no known repair history after 1938.

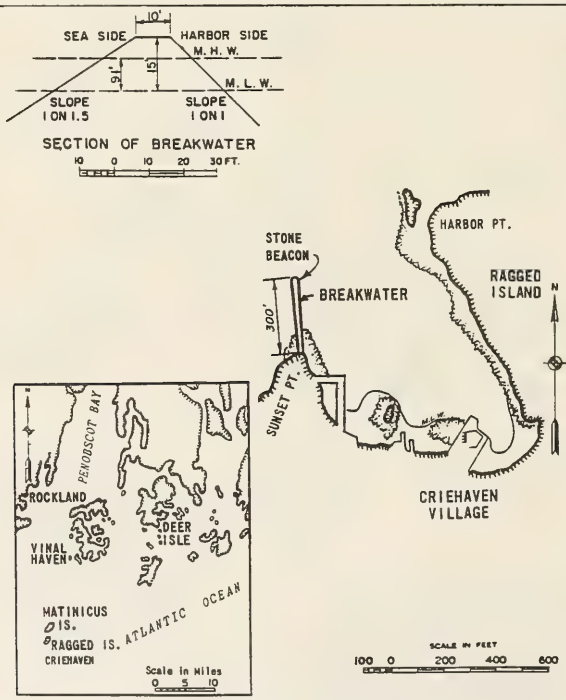


Figure 7. Breakwater located at Criehaven Harbor, Maine

Table 7

Rockland Harbor Breakwater

Rockland Harbor, Maine

Date(s)	Construction and Rehabilitation History
1881-1904	A 4,346-ft-long rubble-mound breakwater was constructed using 788,500 tons of stone (Figure 8). The structure was built to +14 ft mlw with a 15-ft top width and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively (Figure 8, inset). The mean tide range was 9.7 ft.
1925	The breakwater was repaired using 6,500 tons of stone at a cost of $14,000.
1960-1983	Visual inspections during this period indicated that the breakwater was in good condition.

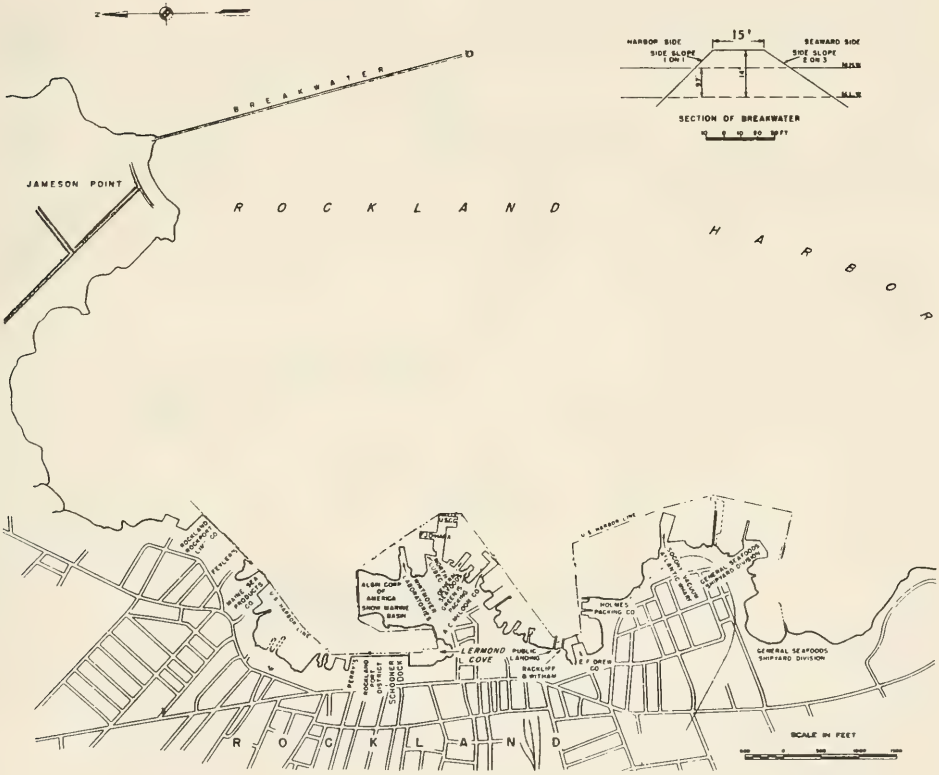


Figure 8. Breakwater located at Rockland Harbor, Maine

Table 8

Cape Elizabeth-Richmond Island Breakwater

Richmond Island Harbor, Maine

Date(s)	Construction and Rehabilitation History
1881	A 2000-ft-long rubble-mound breakwater was constructed between Cape Elizabeth and Richmond Island providing a harbor of refuge for commercial schooners (Figure 9). Cost of construction totaled $120,000. The mean tide range was 8.9 ft.
1986	Although there are no commercial or municipal service facilities at Richmond Island Harbor, it is used extensively for anchorage by large and small recreational craft. Apparently, the breakwater has never been repaired.

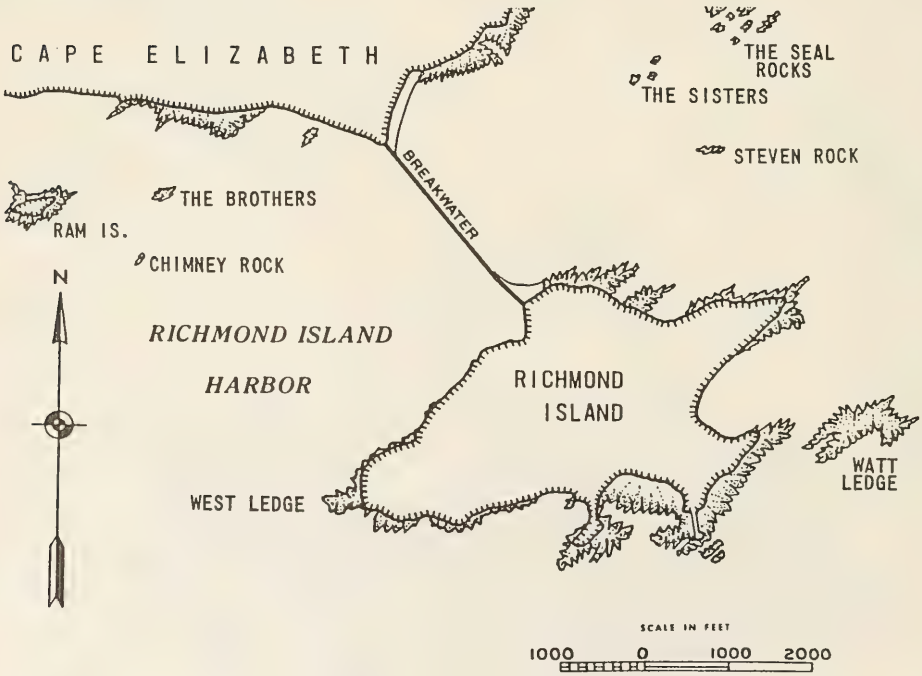


Figure 9. Location map of breakwater at Richmond Island Harbor, Maine

Table 9

Portland Harbor Breakwaters

Portland, Maine

Date(s)	Construction and Rehabilitation History
1836	A 2,000-ft-long stone breakwater was constructed on the south side of the Portland ship channel (Figure 10, location map). Since construction, the majority of the breakwater has been backfilled forming the eastern end of the South Portland waterfront.
1950-1951	An additional 900-ft-long stone breakwater was constructed easterly of the original structure (Figure 10). The cross section consisted of a 15-ft crown width with a +15 ft mlw crest el and slopes of 1V:1.25H and 1V:2H on the harbor and sea sides, respectively. The core stone was 0.5 to 5 tons each and the cover stone, comprising 75 percent of total tonnage, was 5 to 11+ tons each. Total stone placed was 48,000 tons at a cost of $198,700.
1967-1985	During this time frame, visual inspections indicated that both breakwaters were in good condition. The newer 900-ft-long breakwater had some slope stone slippage.
1986	The breakwaters have no known repair history.

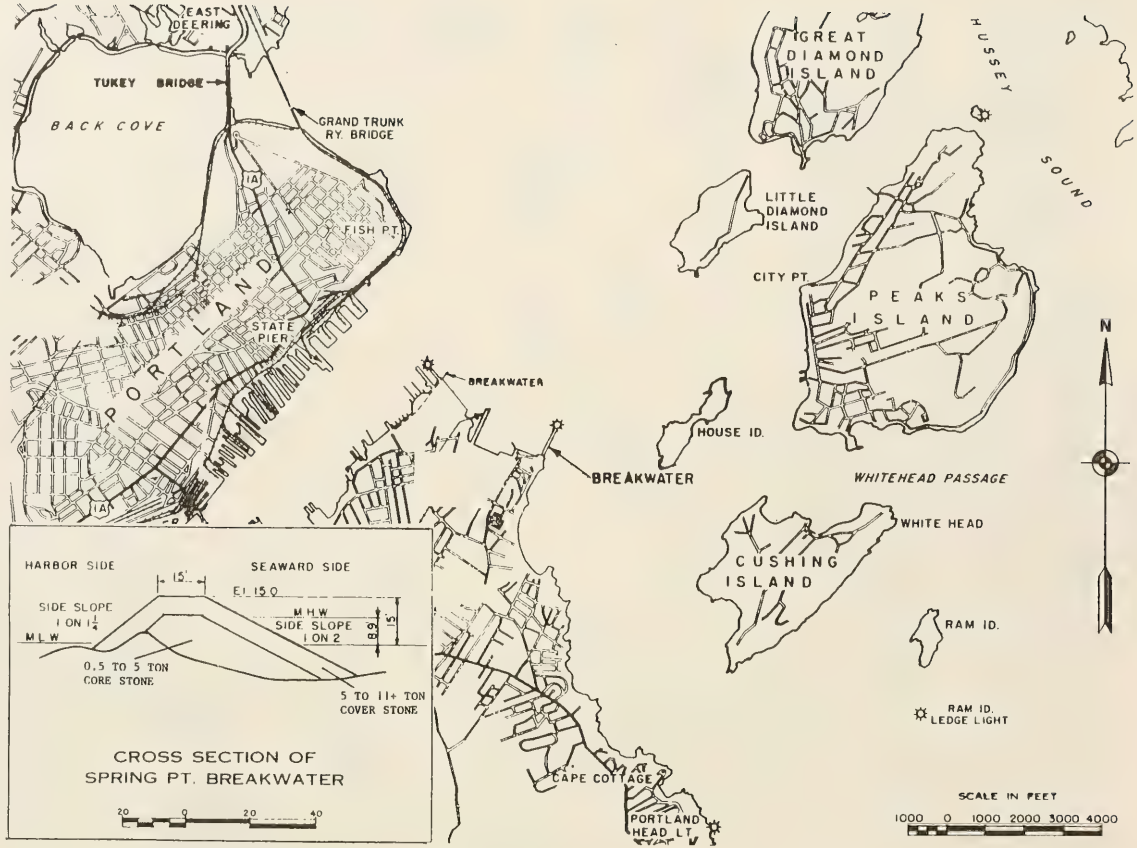


Figure 10. Location map of breakwaters at Portland Harbor, Maine

Table 10

Pine Point Jetty

Scarboro River, Maine

Date(s)	Construction and Rehabilitation History
1962	An 800-ft-long rubble-mound jetty was constructed at Pine Point (Figure 11, location map) using 25,600 tons of stone at a cost of $155,100. The typical design section (Figure 11, inset) had a +13 ft mlw top elevation, a 5-ft top width, 1V:1.5H side slopes, and a 1.5-ft-thick bedding layer. The cover layer consisted of 2- to 4-ton stone, and the core and bedding stones were less than 150 lb each.
1963-1985	Visual inspections revealed the jetty to be in good condition. Some erosion of bottom material was noted along the jetty's seaward side toe.
1986	The jetty does not have a repair history.

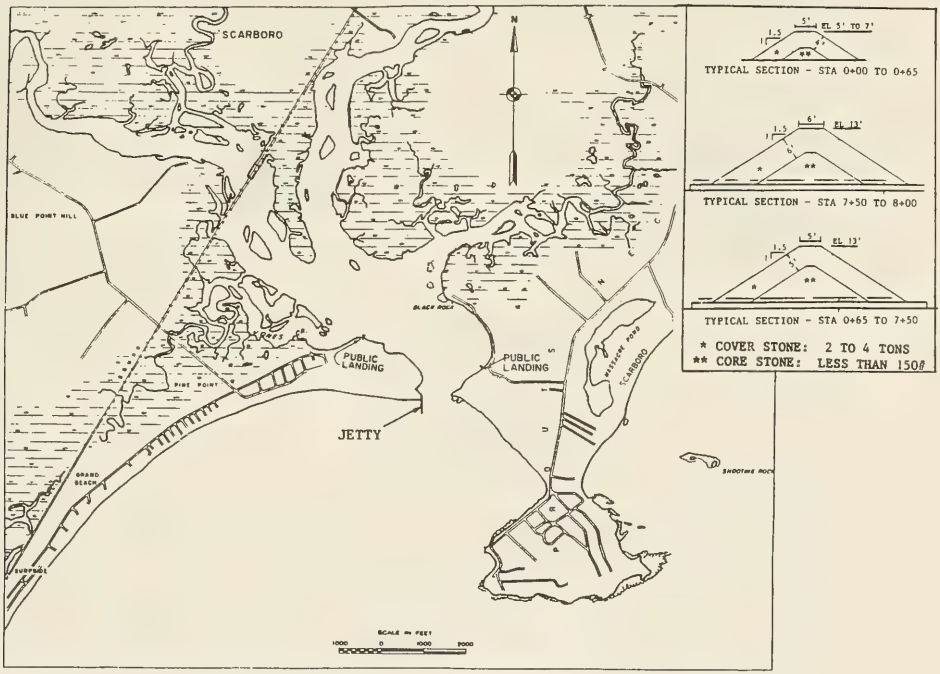


Figure 11. Location map and typical cross sections of Scarboro River jetty, Scarboro, Maine

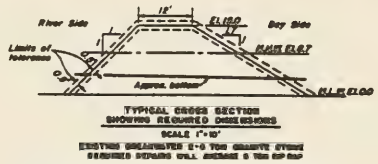
Table 11

Saco River Jetties

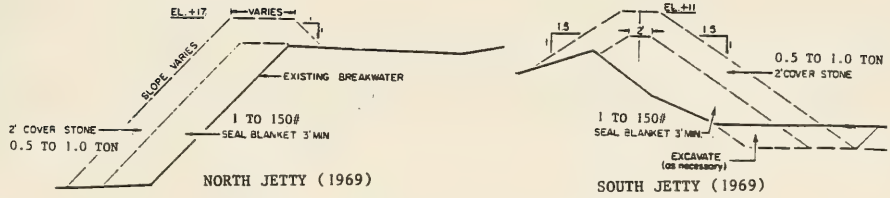
Mouth of the Saco River, Maine

Date(s)	Construction and Rehabilitation History
1873-1912	During this period (noninclusive) the north (Sharp's Ledge) and south (Hills Beach) jetties were constructed to lengths of 4,100 and 4,800 ft, respectively. The north jetty had an elevation of +15 ft mlw and an 8-ft crown width. The south jetty top elevation and width were +5.5 ft mlw and 10 ft, respectively. Jetty side slopes were 1V:1H. The jetties are roughly parallel and spaced 700 ft apart (Figure 12, present plan view). The south jetty extended approximately 1,600 ft bayward of the north jetty. The mean tide range is 8.8 ft.
1927-1930	The north jetty was extended 1,600 ft bayward. The design cross section was identical to that used on the south jetty. The extension resulted in adjacent bayward ends of the jetties. Repairs were made on the outer 1,600 ft of the south jetty. The repair cross section was identical to the original design. Extension and repair costs totaled $53,800 with approximately 18,100 and 2,450 tons of stone placed on the north and south jetties, respectively.
1934-1938	The north jetty was extended 900 ft bayward, and at the landward end a 160-ft section was repaired. The extension gave the jetty a total length of 6,600 ft, and the design cross section was similar to that of the previous extension. The design cross section for the landward repairs specified a +18 ft mlw elevation, a 12-ft crown width, and 1V:1H side slopes.
1958	The landward 700 ft of the north jetty were repaired to a crown elevation of +15 ft mlw, a 12-ft crown width, and slopes of 1V:1H and 1V:1.7H on the channel and bay sides, respectively. Stone size varied from 0.5 to 7 tons or more, with 75 percent of the stone averaging more than 5 tons apiece. Prior to the repairs, existing center-line elevations varied from +9 to +15 ft mlw. A total of 5,100 tons of stone was placed for a cost of $38,000.
1969	Repairs were made at the landward ends of the jetties by placing a seal blanket of 1- to 150-lb stone and 0.5- to 1.0-ton cover stone. Repair sections were 1,000 and 1,100 ft in length on the north and south jetties, respectively. The repair geometry was placed on the bayside slope of the existing jetty sections, with a minimum blanket thickness of 3 ft and a 2-ft cover layer. The north jetty design geometry had a +17 ft mlw crown elevation, various crown widths from 3 to 12 ft, a variable bayside slope matching the existing slope, and a 1V:1H channel side slope. The south jetty design geometry consisted of a +11 ft mlw crown elevation, 3-ft crown width, and 1V:1.5H side slopes. The cost for placing 16,600 tons of stone was $199,000.

(Continued)



NORTH JETTY REPAIR SECTION (1958)



NORTH JETTY (1969) SOUTH JETTY (1969)

Figure 12. Plan view and typical sections of Saco River Jetties, Saco, Maine

Table 11 (Concluded)

Date(s)	Construction and Rehabilitation History
1971	About 650 ft of shoreline revetment was placed landward of the south jetty terminus. The cost for placing 7,350 tons of stone and 3,000 cu yd of sand fill was $93,100.
1983	An inspection indicated the south jetty was in good condition. The 1968 north jetty repair section was in good condition, but the remainder of the jetty was in poor condition.

Table 12

Kennebunk River Jetties

Kennebunk, Maine

Date(s)	Construction and Rehabilitation History
1829-1893	The history of the jetties dates back many years prior to 1829 when the Federal government made its first appropriation for repair of the wooden piers built by local interests to protect the river entrance. Subsequent enactments provided funds to repair these structures, and during the period 1829-52 granite piers were erected at the entrance. The west jetty was completed in 1871 to dimensions of 160 ft for the wing wall and 290 ft for the main trunk. The east jetty is 534 ft long and has a 232-ft wing wall at its landward end (Figure 13). The structures consisted of regularly shaped cut stone placed in pyramid fashion (Figure 13, inset), and resulting side slopes varied from 3V:1H to vertical. Top elevations on the east and west jetties were +16 to +17 ft mlw and +13 ft mlw (+16 ft mlw on pier at seaward end), respectively. The top one or two rows of stone were held together with steel dowels. Width of the top row of stones varied from 2 to 6 ft. The jetties, spaced about 250 ft apart, converge slightly in the seaward direction with the east jetty approximately 350 ft farther seaward. Stone piers of similar construction were placed at the seaward ends of the jetties. The piers were square shaped in plan view and two to three times larger in cross section. Apparently, the jetties were repaired in the early 1890's. Other repair work may have been completed between 1895 and 1930.
1931	The east jetty was repaired by resetting 300 tons of wall stone, placing 212 tons of rubble stone, placing 165 cu yd of concrete, and adding 50 iron pins to the capstone for a total cost of $3,000.
1935	The jetties were repaired by resetting 85 tons of wall stone, placing 504 tons of rubble stone, and placing 20 cu yd of concrete for a total cost of $2,800.
1954	Three sections of the east jetty, totaling 59 lin ft, were repaired by replacing stone to the general dimensions of adjacent undamaged sections of the jetty. Cost of the repairs was $9,400.
1962	The jetties were repaired by resetting stone and placing concrete at several locations, and a stone berm was placed around the west jetty stone pier. The repair sections were typically 1 to 8 cu yd in volume. The stone berm around the west jetty head was placed to an elevation of +12 ft mlw and a 1V:1.5H side slope, and it consisted of stone weighing a minimum of 2 tons. Total cost of the repairs was $12,900.

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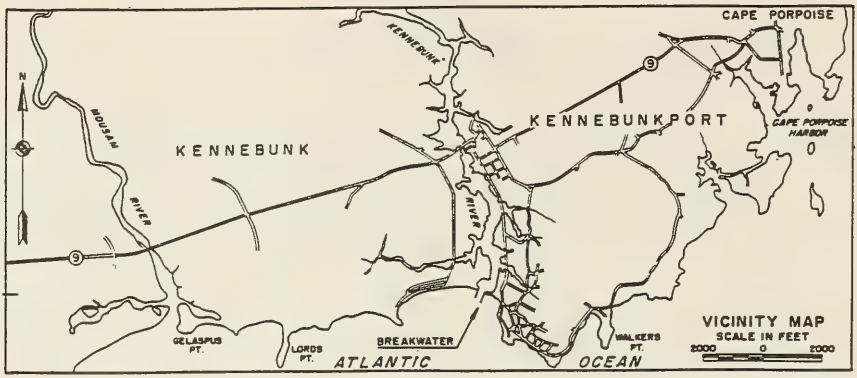
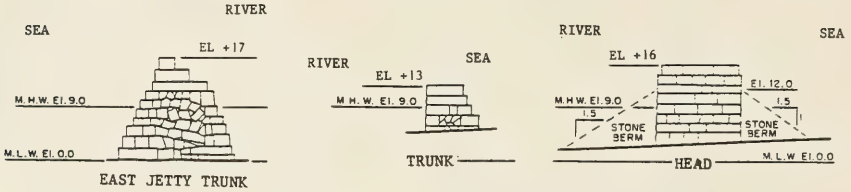
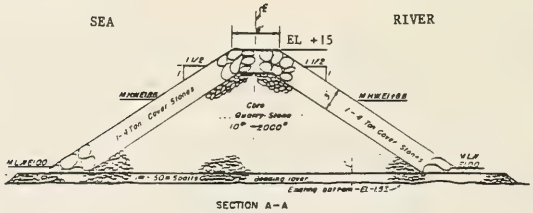
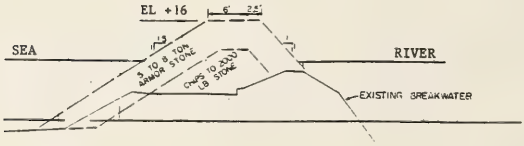




WEST JETTY AND SEAWARD
STONE BERM (1962)



WEST JETTY EXTENSION (1964-65)



EAST JETTY REPAIR SECTION (1969)

Figure 13. Plan view and typical cross sections of Kennebunk River jetties, Kennebunk, Maine

Table 12 (Continued)

Date(s)	Construction and Rehabilitation History
1964-1965	The west jetty was extended 300 ft seaward as part of improvements which included deepening the 100-ft-wide channel from -4 to -8 ft mlw. The purpose of this extension was to reduce potential channel shoaling. Constructed parallel to and 250 ft from the east jetty, the extension brought the outer ends of the jetties abreast of one another. The rubble-mound cross section was placed to +15 ft mlw, a 6-ft crown width, and side slopes of 1V:1.5H. The section was made up of a 1-ft-thick bedding layer of 1-to 50-lb stone, a core of 10- to 2,000-lb stone, and a 3-ft-thick cover layer of 1- to 4-ton stone. The outward facing semicircle at the jetty head had an 8-ft crown width, 1V:2H side slopes, and a 4-ft-thick cover layer of 3- to 7-ton stone. A total of 950 cu yd of bedding stone and 9,000 tons of core and cover stone were placed for a cost of $70,000. Cover stone size was selected using Hudson's slope stability formula and depth-limited wave heights of 7.5 and 10.5 ft for the trunk and head, respectively.
1969	Repairs were made by placing quarried stone on the east jetty seaward slope from approximately 1+00 to 5+00. Also included were repairs of an undermined channel side section between 2+50 and 2+60 and a breeched section, with a maximum depression of about 9 ft, between 3+20 and 3+50. Prior inspections between 1964 and 1967 indicated the jetty was in poor condition. The seaward slope armor stone was placed to +16 ft mlw, a minimum, composite top width of 6 ft (including the existing capstone), and a 1V:1.5H side slope. The core consisted of chips to 2,000-lb stone, and the cover layer was 5- to 8-ton stone. The damaged sections were repaired by resetting existing stone blocks and adding new stone. The design channel side slope was 1V:1H. A total of 5,600 tons of stone was placed for a cost of $100,800. The west jetty was in good condition with only minor displacement of armor stone along the recent extension.
1977-1978	Visual inspections indicated the jetties were in poor condition. On the east jetty the seaward side of the head (stone pier) was severely damaged, void spaces in the seaward slope armor stone were evident, and the channel side toe was in a deteriorated state due to undermining. On the west jetty extension the outer 150 ft had large amounts of displaced cover stone with typical elevations from +6 to +13 ft mlw. The remainder of the extension was in considerably better shape with only minor displacement and settlement of the armor stone.
1981	The jetties were repaired with armor stone along the damaged sections observed on previous inspections and a topographic survey. The channel side of the east jetty, from 1+66 to 3+80, was repaired with 5- to 8-ton stone placed to an elevation of +12 ft mlw, a 1V:1H side slope, and a top width varying from 0 to 4 ft. The east jetty's seaside was repaired between 4+20 and 5+24 using 5- to 8-ton stone

(Continued)

Table 12 (Concluded)

Date(s)	Construction and Rehabilitation History
1981 (cont.)	placed to a +16 ft mlw crown elevation. The crown width and side slope were 6 ft and 1V:1.5H, respectively, except seaward of 5+00 where they were 30 ft and 2V:1H, respectively. The seaward 200 ft of the west jetty was brought up to the original design geometry with 3- to 5-ton and 3- to 7-ton stone on the trunk and head sections, respectively. Total cost for placing 2,100 tons of stone was $99,000. Figure 14 is a photograph of the jetties taken prior to the repairs.
1986	Present conditions of the jetties are not known.

Figure 14. March, 1981 photograph of jetties at the mouth of the Kennebunk River, Maine

Table 13

Wells Harbor Jetties

Wells Harbor, Maine

Date(s)	Construction and Rehabilitation History
1961-1962	Two rubble-mound jetties were constructed to protect the 8-ft-deep channel to Wells Harbor. The north and south jetties, 580 and 920 ft long, respectively, converged at approximately a right angle to a distance of 420 ft where the north jetty terminated and the 340-ft seaward leg of the south jetty began (Figure 15, present plan view). Design crown elevations varied from +13 ft mlw at the jetties' seaward ends to +17 and +16 mlw at the landward ends of the north and south jetties, respectively. Crown widths were 5 and 7 ft along landward and seaward jetty sections, respectively. Specified side slopes were 1V:1.5H. A 1-ft-thick bedding layer and core of 3-in. to 150-lb stone was covered with a double layer of stone weighing a minimum of 2 and 3 tons on landward and seaward sections, respectively. The cost for placing 20,000 tons of stone was $95,600.
1962-1963	The north jetty was extended 200 ft seaward, and 100 ft of stone wave absorber was placed on the landward, channel side of the south jetty. Additional work included placing 650 ft of stone revetment and fill material at the south jetty's landward end. The north jetty extension, constructed parallel to the south jetty's seaward leg, had a +13 ft mlw crown elevation, an 8-ft crest width, and 1V:1.5H side slope (Figure 15, inset). The section consisted of a core and 1.5-ft- thick bedding layer of 0- to 700-lb stone, followed by a 2-ft-thick underlayer of 1,000- to 2,000-lb stone, and covered with a layer of 5- to 7-ton stone. The south jetty wave absorber was 5 ft thick, had a top elevation of +14 ft mlw, and a 1V:1.5H side slope. A double layer of 1- to 2-ton (minimum) stone placed on a 1.5-ft-thick bedding layer of 0- to 200-lb stone comprised the wave absorption material. The jetty extension cost $29,600 using 3,800 tons of stone, while the costs of the revetment, wave absorber, and fill material amounted to $38,400.
1966	The north and south jetties were extended seaward 1,225 and 1,300 ft, respectively. Extensions were parallel to one another, spaced 425 ft apart, and terminated at a depth of -8 ft mlw. The design geometry consisted of a +16 ft crown elevation, a 12-ft crown width, and 1V:1.5H side slopes. The section was built up on a 1.5-ft-thick bedding layer of 1- to 50-lb stone, followed by a core of 1- to 300-lb stone, followed by a 4-ft-thick underlayer of 0.4- to 1-ton stone, and covered with a layer of 4- to 6-ton stone. The 100-ft-long jetty heads required 1V:2H side slopes, a 5-ft-thick underlayer of 0.5- to 2-ton stone, and two layers of 8- to 12-ton cover stone. A total of 119,000 tons of stone was placed at a cost of $594,600.
1968-1985	Visual inspections indicate the jetties were in good to excellent condition.

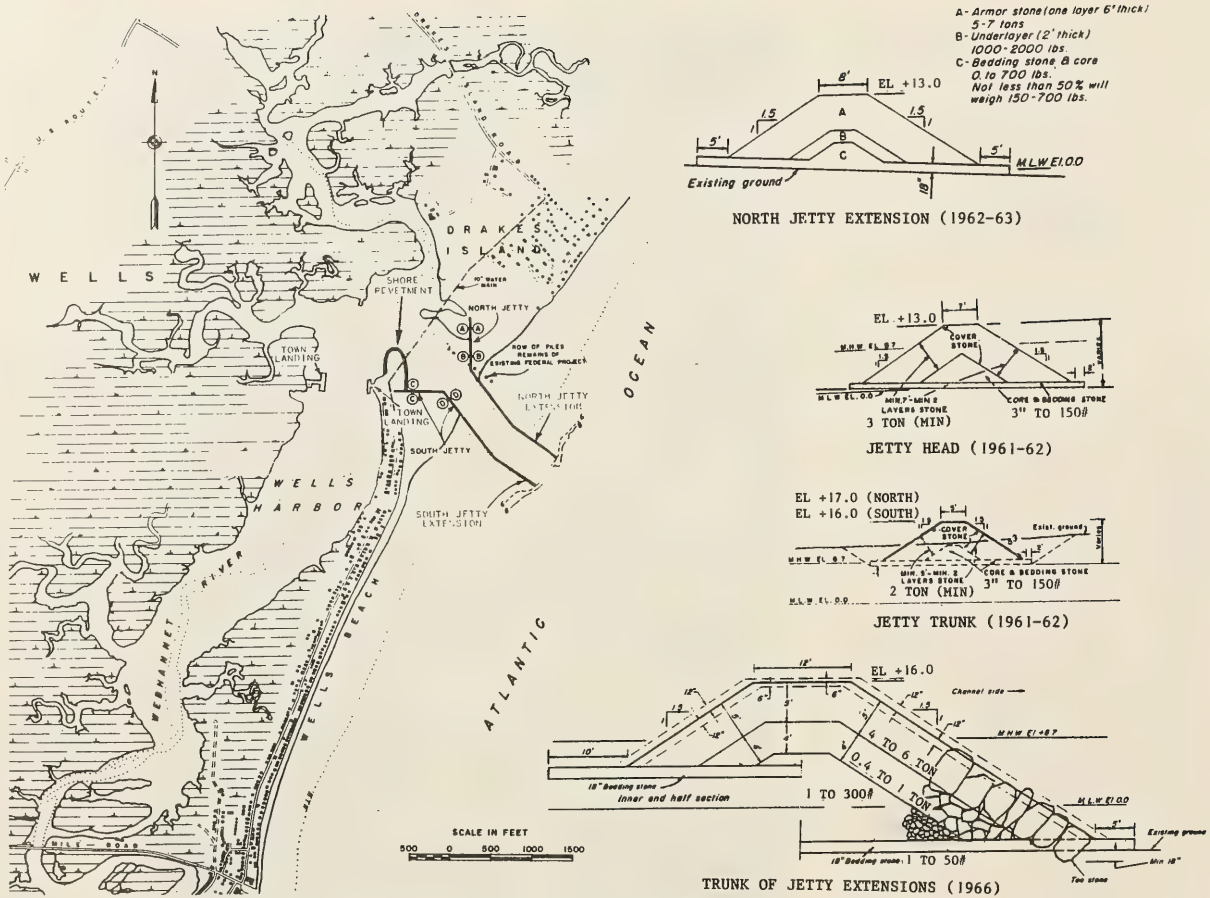


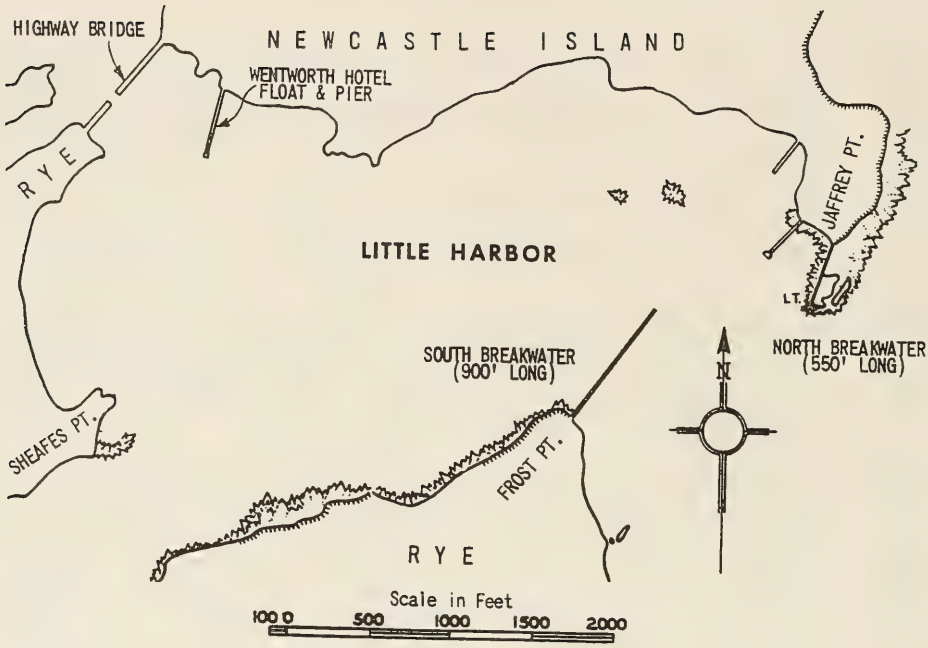
Figure 15. Plan view and typical cross sections of jetties at Wells Harbor, Maine

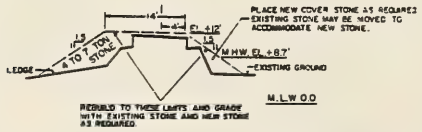
Table 14

Little Harbor Breakwaters

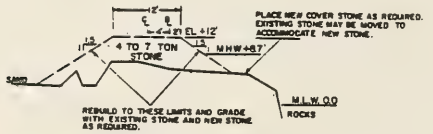
Little Harbor, N.H.

Date(s)	Construction and Rehabilitation History
1894-1903	Two rubble-mound breakwaters were constructed to lengths of 550 and 900 ft on the north and south sides of the entrance to Little Harbor (Figure 16).
1905	Minor repairs were made using 476 tons of stone.
1959-1974	Based on several visual inspections, the jetties were considered to be in poor condition.
1975	Seaward sections of the north and south jetties, 350 and 850 ft long, respectively, were repaired using 4 to 7-ton stone. The design cross section (Figure 16, inset) had a +12 ft mlw crown elevation, a 12- or 14-ft top width, and 1V:1.5H side slopes. The side slope on the seaward facing quadrant of the breakwater heads was 1V:2H. The cost for placing 7,800 tons of stone was $159,500.
1983	An inspection showed that the north jetty had a few small areas of displaced stone, and the south jetty had substantial damage which was subsequently repaired along the seawardmost 150 ft.
1985	Visual inspection indicated the breakwaters were in good condition.





TYPICAL SECTION-NORTH BREAKWATER (1975)



TYPICAL SECTION-SOUTH BREAKWATER (1975)

Figure 16. Plan view and cross sections of breakwaters at Little Harbor, N.H.

Table 15

Isles of Shoals Breakwaters

Isles of Shoals, N.H. and Maine

Date(s)	Construction and Rehabilitation History
1821-1904	Two rubble-mound breakwaters were constructed between Malaga, Smuttynose, and Cedar Islands (Figure 17). Approximate lengths of the Malaga Island to Smuttynose Island and Smuttynose Island to Cedar Island breakwaters were 150 and 650 ft, respectively.
1913	A 530-ft-long rubble-mound breakwater was constructed between Cedar Island and Star Island using 34,000 tons of stone at a cost of $39,000.
1929	The Cedar Island to Star Island breakwater was repaired.
1955	A section of the Cedar Island to Star Island breakwater (350 ft long and adjacent to Star Island) was repaired placing armor stone weighing 5 to 11+ tons and resetting of displaced stone. The design section (Figure 17, inset) called for a +14 ft mlw crown elevation, a 10-ft crown width, and slopes of 1V:1.5H and 1V:1H on the sea and harbor sides, respectively. Total cost was $34,900 for placing and resetting 1,640 and 1,140 tons of stone, respectively.
1967	The Cedar Island to Star Island breakwater was inspected and found to be in poor condition. Plans and specifications were prepared for repairing a 500-ft section adjacent to Star Island. But, due to contract bids substantially above the Government estimate, no contract was awarded. The plans show the breakwater to be approximately 650 ft long with a 200-ft dogleg section adjacent to Star Island, apparently adding 120 ft to the original length . Existing center-line elevations were typically from +9 to +13 ft mlw along the proposed repair section.
1974	About 575 ft of the Cedar Island to Star Island breakwater, adjacent to Star Island, were repaired using 6- to 10-ton stone. Prior to repair, typical center-line elevations varied from +6 to +10 ft mlw. The stone was placed to an elevation and top width of +15 ft mlw and 20 ft, respectively. Slopes were 1V:2H and 1V:1.5H on the sea and harbor sides, respectively. In addition to 14,000 tons of new stone, displaced stone on the harbor side was used in reconstructing the lower portions of the breakwater. The repair cost was $665,000.
1983	Visual inspections of the Cedar Island to Star Island and Cedar Island to Smuttynose Island breakwaters indicate the former was in good condition, while the latter was in fair to poor condition with a significant amount of damage along its midsection.
1986	Present conditions of the breakwaters are not known.

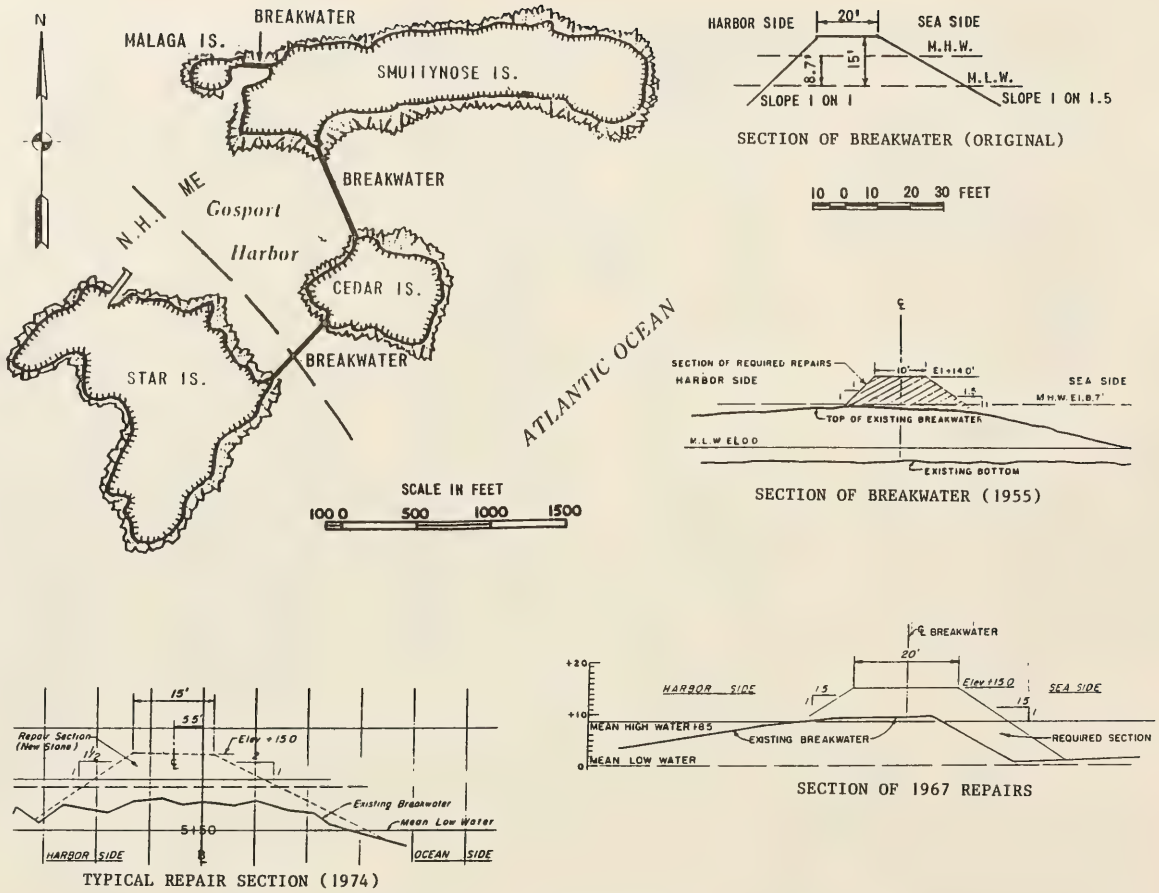


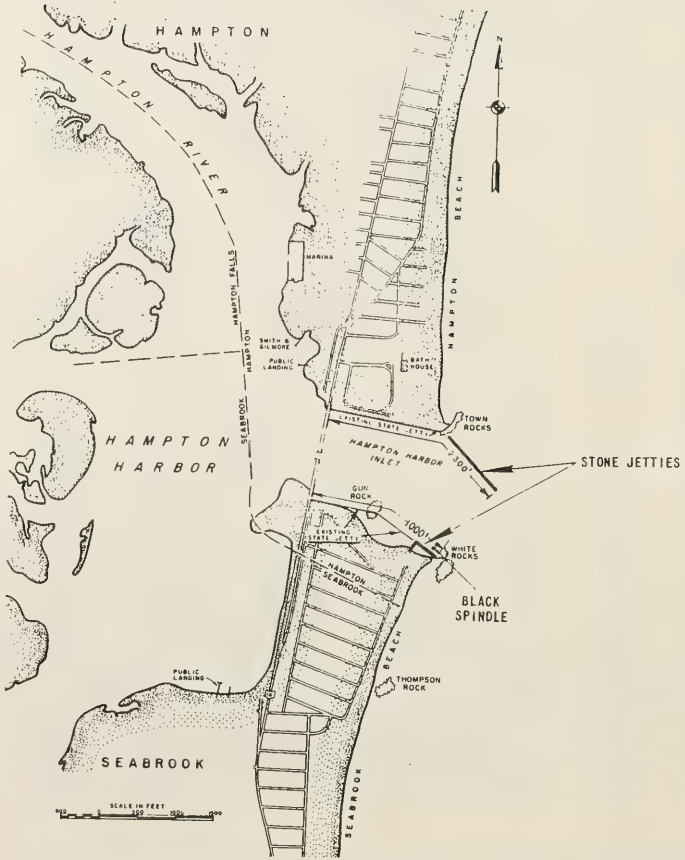
Figure 17. Breakwaters at Isles of Shoals, Maine, and N.H.

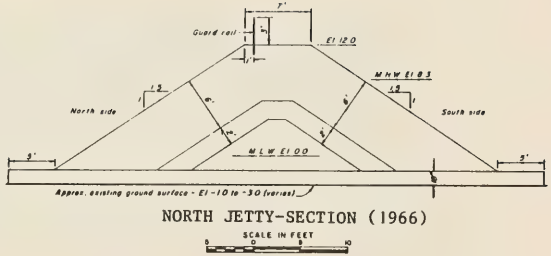
Table 16

Hampton Harbor Jetties

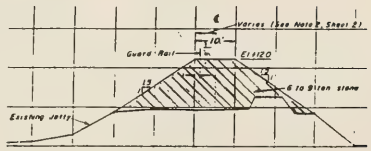
Hampton Harbor, N.H.

Date(s)	Construction and Rehabilitation History
1933-1935	Two stone jetties were constructed by the New Hampshire State Highway Department to lengths of 1,300 and 1,000 ft on the north and south sides of Hampton Harbor Inlet, respectively.
1966	The Federal government extended the north jetty seaward 1,000 ft, repaired the outer 300 ft of south jetty, and constructed a 180-ft-long landward-perpendicular spur at the inner end of the south jetty repairs (Figure 18). Crown elevations of the north and south jetties were +12 and +16 ft mlw, respectively. Crown width and side slopes were 5 ft and 1V:1.5H, respectively. The jetty section was built with a 1.5-ft-thick bedding layer of 1- to 50-lb stone, a core of 1- to 300-lb stone, a 2-ft-thick underlayer of 400-to 1,000-lb stone, and a cover layer of 2- to 3-ton stone. The 150-ft seaward section of the north jetty had a 7-ft crown width and a cover layer of 3- to 4-ton stone. The north jetty head semicircle had a 1V:2H side slope. The bedding layer extended 5 ft beyond the cover layer toe. As constructed, the crown consisted of a single row of cap stones. The cost for placing 36,670 tons of stone was $272,400.
1969	Plans and specifications were prepared for north jetty repairs, but no work was done at this time. The outer 110 ft was in an unraveled condition with typical center-line elevations from +3 to +10 ft mlw.
1973 1974	The north jetty extension was repaired. Prior to repair, the jetty had numerous void spaces and gaps along its entire length. The seaward 300 ft was in a severely unraveled state with typical crest elevations between 0 and +10 ft mlw. The seaward 490 ft was brought up to +12 ft mlw with 6- to 9-ton stone placed to an 8- to 10-ft crown width and 1V:1.5H side slopes. The jetty head semicircle had a 1V:2H side slope. The landward 55 ft was rebuilt to the 1966 design geometry with 2- to 3-ton stone. Void areas on the remaining jetty section were repaired with 2- to 3-ton stone. A total of 8,380 tons of stone was placed at a cost of $165,400.
1981	Repairs to the north jetty consisted of placing 4- to 9-ton stone on a 535-ft section at its seaward end. The design geometry was essentially identical to the earlier 1973-74 repair geometry. Before the repairs, typical crown elevations varied from +8 to +12 ft mlw with most of the subsidence ocurring at the seaward end of the repair section. A total of 1,290 tons of stone was placed at a cost of $109,905.
1984	The jetties were inspected and found to be in excellent condition. Figure 19 is an aerial photograph of the jetties taken on 16 October 1984.

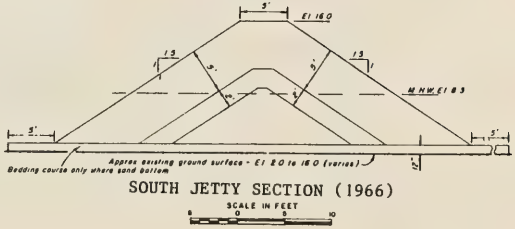




NORTH JETTY-SECTION (1966)



TYPICAL NORTH JETTY REPAIR SECTION (1973)



SOUTH JETTY SECTION (1966)

Figure 18. Jetties at Hampton Harbor, N.H.

Figure 19. October 1984 photograph of jetties at Hampton Harbor, N.H.

Table 17

Newburyport Harbor Jetties

Newburyport, Mass.

Date(s)	Construction and Rehabilitation History
1881-1899	Two rubble-mound jetties were constructed at the mouth of the Merrimack River. The north and south jetties were 4,118 and 2,445 ft long, respectively, and built up to an elevation of +12 ft mlw with a 15-ft top width.
1900-1902	Minor repairs were made on the north jetty using 640 tons of stone.
1905-1909	The south jetty was repaired in 1905 with 850 tons of stone. During 1906-09 a total of 19,800 tons of stone was used in repairing the north jetty. Repair costs during this period totaled $8,730.
1917-1918	The north and south jetties were repaired with 7,140 and 1,750 tons of stone, respectively. Total costs were $18,400.
1925	The north jetty was repaired with 1,600 tons of stone at a cost of $4,600.
1933	The jetties were repaired at a cost of $5,400 for placing 1,190 tons of stone.
1936-1938	Repairs were made to the north and south jetties for a total cost of $143,700 using 29,930 and 7,810 tons of stone, respectively.
1963	An inspection showed both jetties were in poor condition.
1968-1970	Extensive repairs were made to 2,920- and 1,095-ft-long sections of the north and south jetties. The repaired sections would best define the existing lengths of the jetties (Figure 20, plan view). Also completed were 700 lin ft of revetment adjacent to, and landward of, the south jetty repairs. The north jetty repairs started from its reconstructed landward end at 1+00 and continued to the existing seaward end at 30+20. The south jetty repairs started from its reconstructed landward end at 0+00, stopped at 6+00, started again at 10+05 and continued to its reconstructed seaward end at 15+00. An undetermined length of south jetty seaward of 15+00 was not repaired. Seaward of 5+50 both jetties were built up to +12 ft mlw with a 15-ft crown width and slopes of 1V:1H and 1V:2H on channel and sea sides, respectively. The landward sections (Figure 20, inset) had 1V:1.5H side slopes, a crown width of 5 ft, and maximum crown elevations of +17 and +15 ft mlw on the north and south jetties, respectively. The stone size varied from a minimum of 0.5 tons at the landward ends to a maximum of 12 tons at the seaward ends. The estimated quantity of

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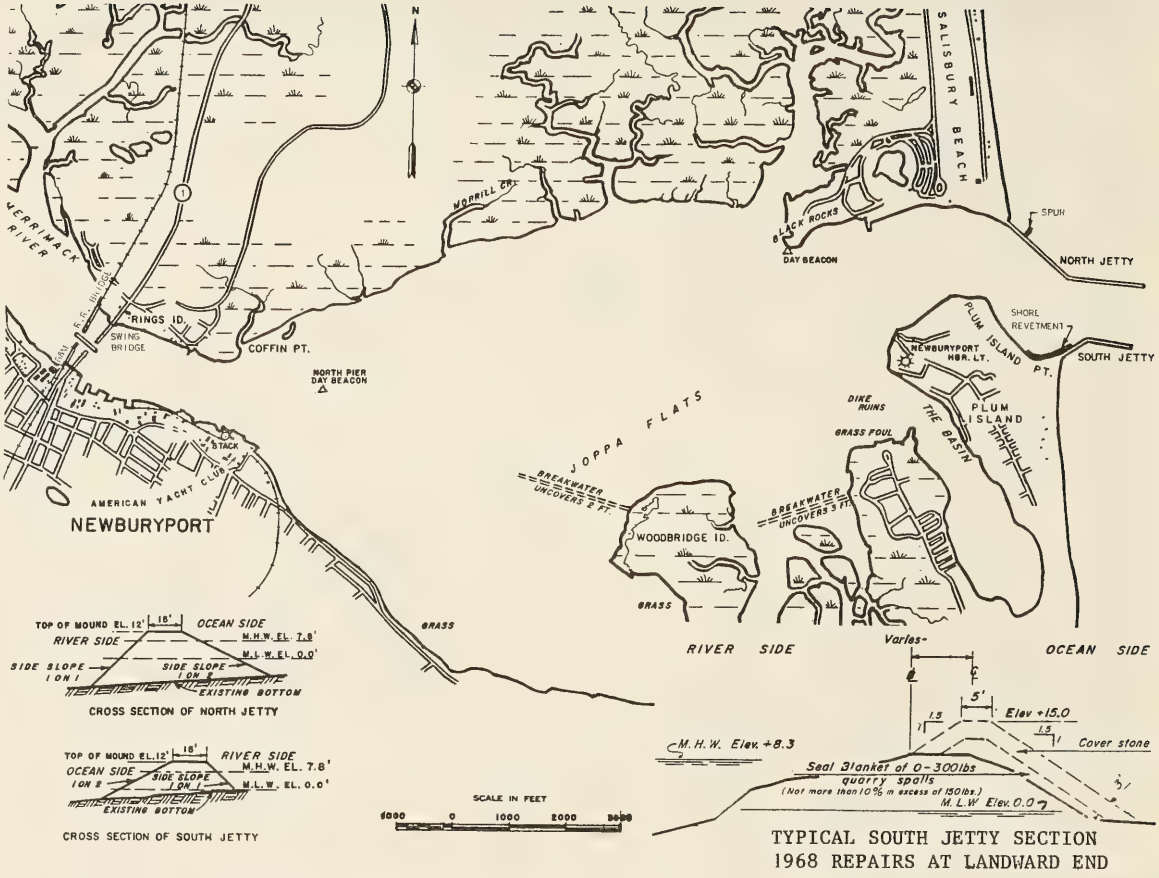

Figure 20. Location map and typical sections of jetties at Newburyport Harbor, Mass.

Table 17 (Concluded)

Date(s)	Construction and Rehabilitation History
1968-1970 (cont.)	stone was 53,600 tons which were to be placed for a total contract cost of $1,267,500. Similarly, the south jetty costs were $221,500 for placing an estimated 13,500 tons of stone and 7,000 cu yd of sand and gravel.
1974	Inspections up to this time indicate the jetties were in good condition overall. Both jetties had isolated areas of settlement, with two areas on the north jetty being severe.
1983-1987	Visual inspection of jetties indicated the jetties were in good condition.

Table 18

Sandy Bay Harbor of Refuge Breakwater

Sandy Bay, Mass.

Date(s)	Construction and Rehabilitation History
1886-1916	Partially completed during this period were 6,100 ft of a planned 9,000-ft-long cut stone and rubble-mound breakwater (Figure 21). The breakwater's southern and western arms were 3,600 and 2,500 ft long, respectively. As built, the breakwater consisted of a rubble-mound substructure built to mlw where the width was 81 ft. Approximately 922 ft of superstructure was constructed at the junction of the breakwater arms. The superstructure consisted of a rubble-mound core and a cover layer of stone blocks stacked horizontally in an overlapping step-wise fashion to elevation of +22 ft mlw, a 20-ft top width, and 1V:1H side slopes. Additional armor stone, weighing a minimum of 10 tons, was placed on the seaward face to a 1V:2H side slope. Total costs were $1,941,500.
1986	The breakwater has no repair history, and the uncompleted portion is inactive. Its original purpose, to provide a harbor of refuge, has become obsolete due to the advent of powered vessels and their ability to seek refuge at existing harbors.

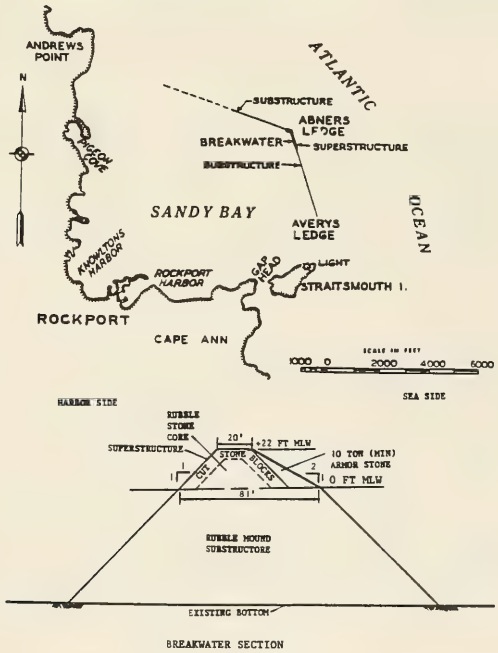

Figure 21. Sandy Bay Harbor of Refuge breakwater and location of Rockport Harbor, Sandy Bay, Mass.

Table 19

Rockport Harbor Breakwaters

Rockport, Mass.

Date(s)	Construction and Rehabilitation History
1836-1839	Two breakwaters of rubble stone were built, one 900 ft easterly from Bearskin Neck and the other about 200 ft northerly from Norwoods Head, leaving an entrance channel 220 ft wide between their low-water lines (Figures 21 and 22). Construction costs totaled $69,200.
1900-1905	By 1900 the breakwaters had deteriorated to the point that they no longer afforded the necessary harbor protection. From 1903 to 1905 repairs were made by placing heavy rubble stone to a height of +18.5 ft mlw, a top width of 20 ft, and slopes of 1V:2H and 1V:1H on the sea and harbor sides, respectively. A total of 11,050 tons of stone was used, and principal rocks were removed from the harbor for a total cost of $22,000.
1958-1967	Inspections indicate the breakwaters were in good condition. Repairs may have occurred in 1952 and 1956. (Information on repairs during the 1950's was not found in the annual reports to the Chief of Engineers.)
1970	Repairs were made at the seaward end of Bearskin Neck breakwater where stone had been displaced from a lower portion of the head side slope. The existing head section cover layer had a fairly smooth appearance due to careful placement and addition of concrete grout. Also, iron tie rods had been placed, connecting individual cover stone throughout this section. The remainder of the breakwater is composed of 500-lb to 5-ton stone with an outward appearance typical of rubble-mound structures. The 45-ft-long repair section was located mostly on the harbor side quadrant of the head. Stone weighing 5 to 8 tons was placed at a 1V:2H side slope. The repairs were made for a lump sum of $25,500.
1973	The seaward end of Bearskin Neck breakwater was repaired with 5- to 8-ton stone. The stone was placed on two sections, one totaling 55 ft in length on the seaside head and trunk and the other totaling 50 ft in length, the same area repaired in 1970. The repairs consisted of adding stone to void areas such that the resulting side slopes were fairly uniform. Lump sum cost of the repair was $28,700.
1977-1978	Repairs were made to the seaward 100 ft of Bearskin Neck breakwater. Existing displaced stone was reset throughout this section and, to complete the repairs, approximately 1,600 tons of new 4- to 8-ton stone were used. The repair geometry had a +18.5 ft mlw crown elevation, a crown width varying from 18 to 28 ft (widest at seaward end), and side slopes varying from 1V:2.5H to 1V:1.5H (steepest at

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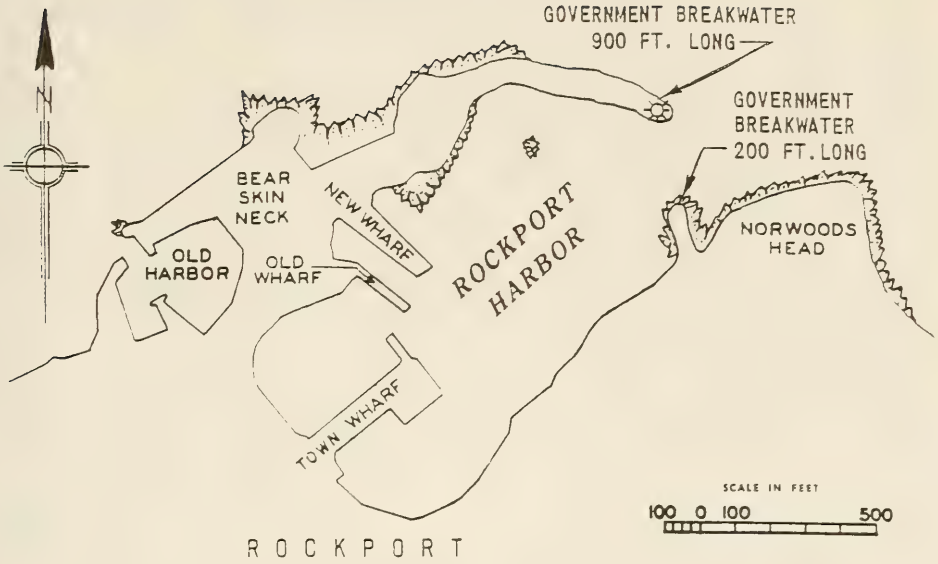

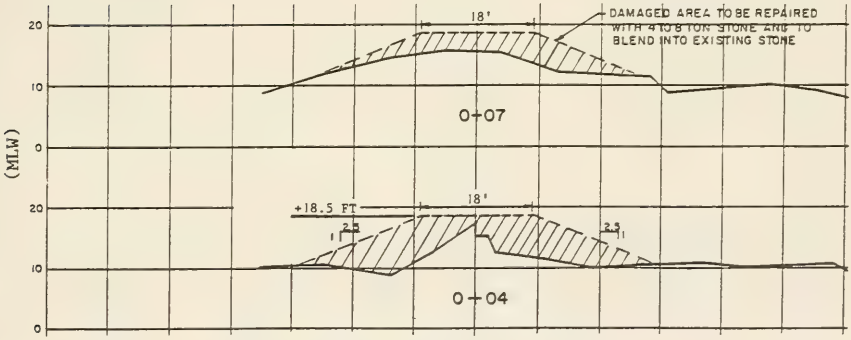

TYPICAL REPAIR SECTION (1977-78)

Figure 22. Breakwaters at Rockport Harbor, Mass.

Table 19 (Concluded)

Date(s)	Construction and Rehabilitation History
1977-1978 (cont.)	seaward end). In 1977, the Norwoods Head breakwater was inspected and found to be in good condition.
1986	Present conditions of the breakwaters are not known.

Table 20

Dog Bar Breakwater

Gloucester Harbor, Mass.

Date(s)	Construction and Rehabilitation History
1894-1906	The 2,250-ft-long Dog Bar breakwater, consisting of a rubble stone substructure below mlw and a stone-block superstructure, was constructed to protect Gloucester Harbor from sea and heavy swells from the south (Figure 23, plan view). The rubble-mound substructure was built to an elevation of 0 ft mlw, where the mound width was 31 ft, a harbor side slope of 1V:1.3H, and a composite sea-side slope of 1V:1.5H and 1V:3H below and above -12 ft mlw, respectively. The substructure stone sizes ranged from 500 lb to 4 tons, except on the seaward side slope where the stone weighed 3 to 5 tons. The superstructure was built up at 1V:0.7H side slopes to an elevation of +17 ft mlw where the crown width was 10 ft. The stone blocks were placed horizontally, in overlapping stair-step fashion, with their lengths perpendicular to the breakwater axis. The blocks were 2 to 3 ft high, 2 to 6 ft wide, 7 to 10 ft long, and weighed 3 to 12 tons each. A row of rubble stone, weighing about 5 tons each, was placed along the superstructure seaward toe. A total of 231,760 tons of stone was placed for a total cost of $398,000.
1931-1940	Minor repairs were made to the superstructure in 1931, 1933-34, 1935, 1939, and 1940. The work (approximate totals in parentheses) included resetting (2,000 tons) and replacing (1,000 tons) stone blocks, placing rubble stone (7,000 tons) on the seaward face (Figure 23, inset), and placing iron pins (700) on the harbor side stone blocks to act as buttressing for the upper courses of stone. The total repair costs were $35,700.
1962	A breakwater inspection showed the stone block superstructure was in good condition with only localized areas needing repair. The sea-side armor stone, placed during 1931-40, was in poor condition with several large cavities and a general subsidence along the entire breakwater length.
1965-1966	Repairs were made to the breakwater superstructure, and 10,920 tons of 6- to 12-ton armor stone were placed on the sea side between 0+00 (landward end) and 21+85. Displaced stone blocks were reset from 1+14 to 1+72 and 9+96 to 10+22. Total cost of the repairs was $96,400.
1967-1978	Breakwater inspections, taken over this period, showed a gradual deterioration of the sea-side armor stone at several locations. Most of the damage was on the outer half of the breakwater.

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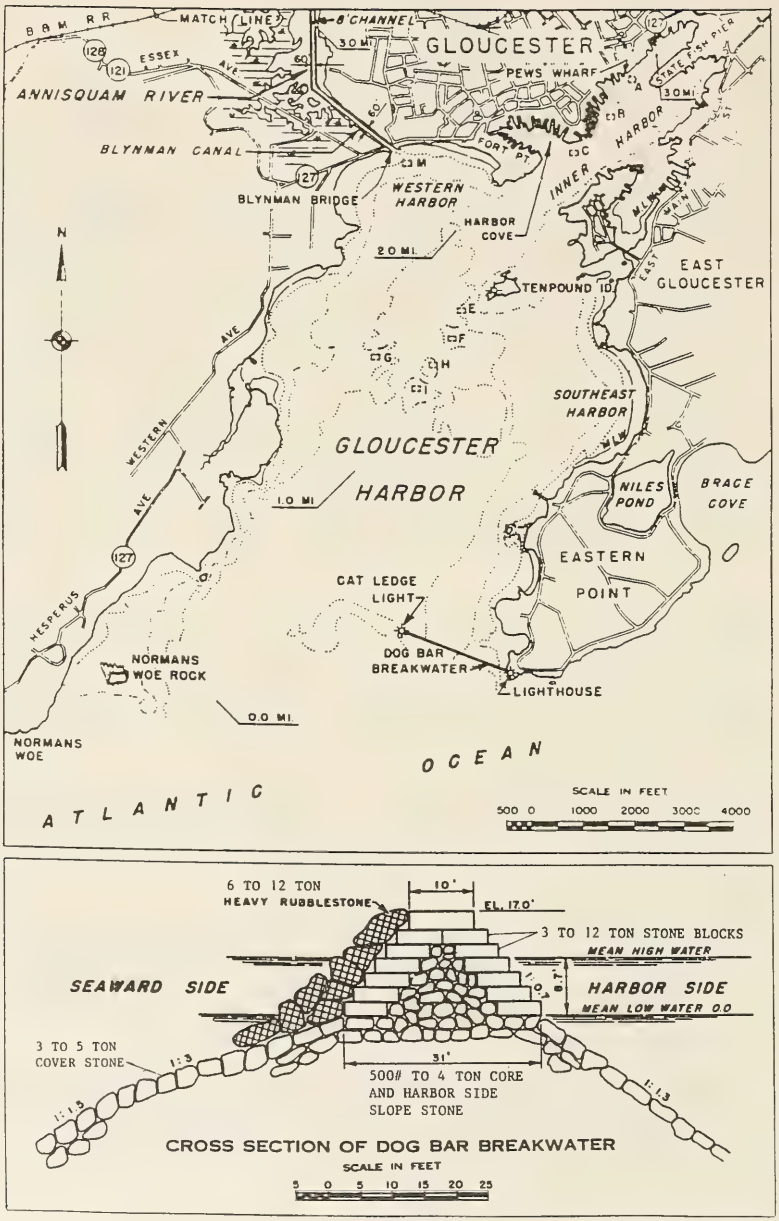


Figure 23. Plan view and typical section of Dog Bar breakwater at Gloucester Harbor, Mass.

Table 20 (Concluded)

Date(s)	Construction and Rehabilitation History
1981	Repairs were made to several sections of the armor stone on the breakwater's seaward slope, and four stone blocks were reset. The 6- to 12-ton armor stone was placed to a 1V:1.5H side slope and a composite (including the top course of stone blocks) crown width of 17 ft. The repairs required an estimated 1,600 tons of stone at the following locations: 7+50 to 8+50, 10+50 to 11+50, 12+00 to 13+50, 15+00 to 17+50, 19+00 to 20+50, and 21+00 to 21+70. Repair costs (based on the estimate) were $70,000.
1986	The breakwater's present condition is not known.

Table 21

Scituate Harbor Jetties

Scituate, Mass.

Date(s)	Construction and Rehabilitation History
1881-1882	A 720-ft-long rubble-mound jetty was constructed on the north side of the entrance to Scituate Harbor (Figure 24). The stone was placed to an elevation of +13.75 ft mlw, a 20-ft crown width, and slopes of 1V:2H and 1V:1H on the sea and harbor sides, respectively. A total of 16,780 tons of stone was used at an approximate cost of $26,000.
1892-1895	A 450-ft-long south jetty (Figure 24) was constructed using 13,040 tons of stone for a total cost of $17,750. The cross-section geometry was identical to that of the north jetty geometry.
1929-1930	Repairs were made over the length of the north jetty using 4,680 tons of riprap for a total cost of $22,000.
1940	The north jetty was repaired and extended 300 ft seaward. The design section consisted of core and cover stone placed to an elevation of +12.75 ft mlw, a 20-ft crown width, and 1V:1.5H side slopes. The extension required placing 18,300 tons of stone for a total cost of $41,000. The repairs were made for a total cost of $7,400 using 3,100 tons of stone.
1960	A topographic survey of the jetties was completed (no details at hand).
1981-1984	Visual inspections of jetties indicated they were in good condition.

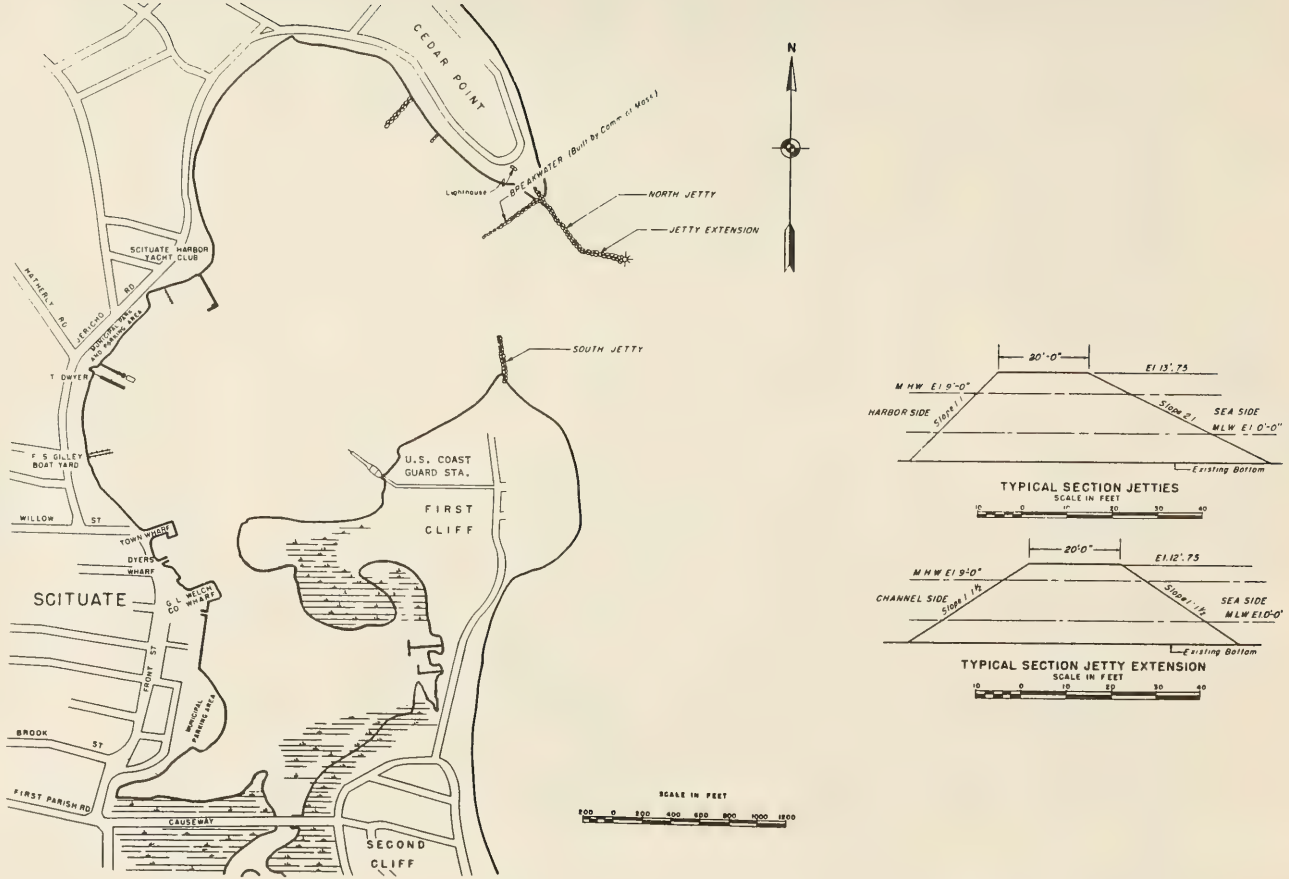


Figure 24. Plan view and typical sections of jetties at Scituate Harbor, Mass.

Table 22

Green Harbor Jetties

Green Harbor, Mass.

Date(s)	Construction and Rehabilitation History
1898-1899	Two rubble-mound jetties were constructed by the Commonwealth of Massachusetts at the entrance to Green Harbor and have been repaired periodically since that time (Figure 25, present plan view). Information on the original jetty lengths was not found.
1931	The state constructed 196 ft of concrete wall at the east jetty's landward end.
1965	The Federal government adopted the project under authority of the River and Harbor Act of 1960.
1968-1969	Repairs were made to seaward sections of both jetties, and the west jetty was extended 200 ft seaward (Figure 25, insets). The east and west jetty repair sections were 494 and 650 ft long, respectively, and consisted of placing a 3- to 4-ft-thick seal blanket of 1- to 50-lb quarry spalls on the seaward slope of the jetties followed by a 2- to 4-ft-thick layer of cover stone. The cover stone was from 4 to 7 tons and 0.5 to 4 tons on the east and west jetty repair sections, respectively. The design geometry, including the west jetty extension, called for a 6-ft crown width, 1V:1.5H side slopes, and crown elevations of +14 and +12 ft mlw on the east and west jetties, respectively. The west jetty extension was built up on a core and 2-ft-thick bedding layer of 1- to 50-lb stone, followed by a 3-ft-thick underlayer of 500- to 1,000-lb stone, and covered with 4- to 7-ton armor stone. The jetties' seaward ends had 1V:2H side slopes. A 175-ft-long dike of 0- to 25-lb stone was placed at the landward end of the west jetty repair section. The stone was placed to a 4-ft top width, 1V:2H side slopes, and a crown elevation increasing from +12 to +14 ft mlw in the landward direction. Prior to the repairs, crown elevations varied from +8 to +11 ft mlw and +6 to +13 ft mlw on the east and west jetty repair sections, respectively. The majority of the east jetty was in a severely unraveled state. Improvements cost $149,000 using a total of 14,900 tons of stone.
1970	Approximately 335 ft of stone revetment was placed at the landward end of the east jetty. The contract price for placing 3,400 tons of stone was $37,400.
1972 1974	Inspection reports indicate the east jetty was in good to excellent condition. West jetty inspections showed the outer 350 ft was severely unraveled and other void areas existed landward of this section. A 1974 topographic survey showed crest elevations in the

(Continued)

Table 22 (Concluded)

Date(s)	Construction and Rehabilitation History
1972-1974 (cont.)	worst areas as low as +4 ft mlw. It was estimated that 1,000 and 500 tons of new and salvageable stone, respectively, were needed to repair the jetty.
1975	The seaward 525-ft section of the west jetty was repaired to the 1968-69 design cross section using 4- to 7-ton cover stone and 500- to 1,000-lb underlayer stone as needed (Figure 25, inset). The repairs were made for a total cost of $40,000.
1977	An inspection indicated that the east jetty was in good condition but that the west jetty needed some armor stone reset.
1986	Yearly inspections indicate that the jetties are in good condition. For the purpose of this report, the lengths of the east and west jetties are considered to be 645 and 850 ft long, respectively (the 1968-69 improvements plus approximately 150 ft of concrete wall landward of the east jetty repair section).

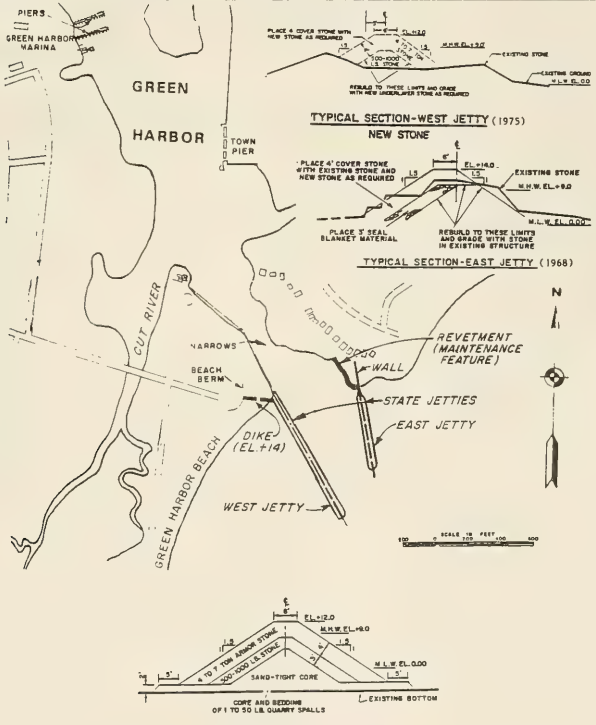


Figure 25. Plan view and cross sections of jetties at Green Harbor, Mass.

Table 23

Plymouth Harbor Breakwater

Plymouth, Mass.

Date(s)	Construction and Rehabilitation History
1968-1971	A rubble-mound breakwater, with east and west legs 2,100 and 1,400 ft long, respectively, was constructed providing protection to recreational and commercial vessels using Plymouth Harbor (Figure 26, plan view). The design crown elevation was +15 ft mlw, but to allow for foundation settlement the construction elevations were +16 and +15.5 ft mlw on the east and west legs, respectively. The crown width was 7 ft, and side slopes were 1V:1.5H. The breakwater cross-section was made up of 2-ft-thick bedding layer of 0- to 12-in. stone, followed by a core of 0- to 600-lb stone, and the 3-ft-thick outer layer required stone weighing a minimum of 600 lb and 2 tons on the side slopes and crown, respectively. The stone size was based on Hudson's slope stability formula and a design wave height of 3.5 ft, and the crown elevation was based on a design tide of +12.7 ft mlw. The contract price for breakwater construction, using an estimated total of 219,000 tons of stone, was $1,145,100.
1972-1978	Inspections during this period showed the breakwater was in excellent condition.
1982-1984	Visual inspections of the breakwater indicated it was in good condition.

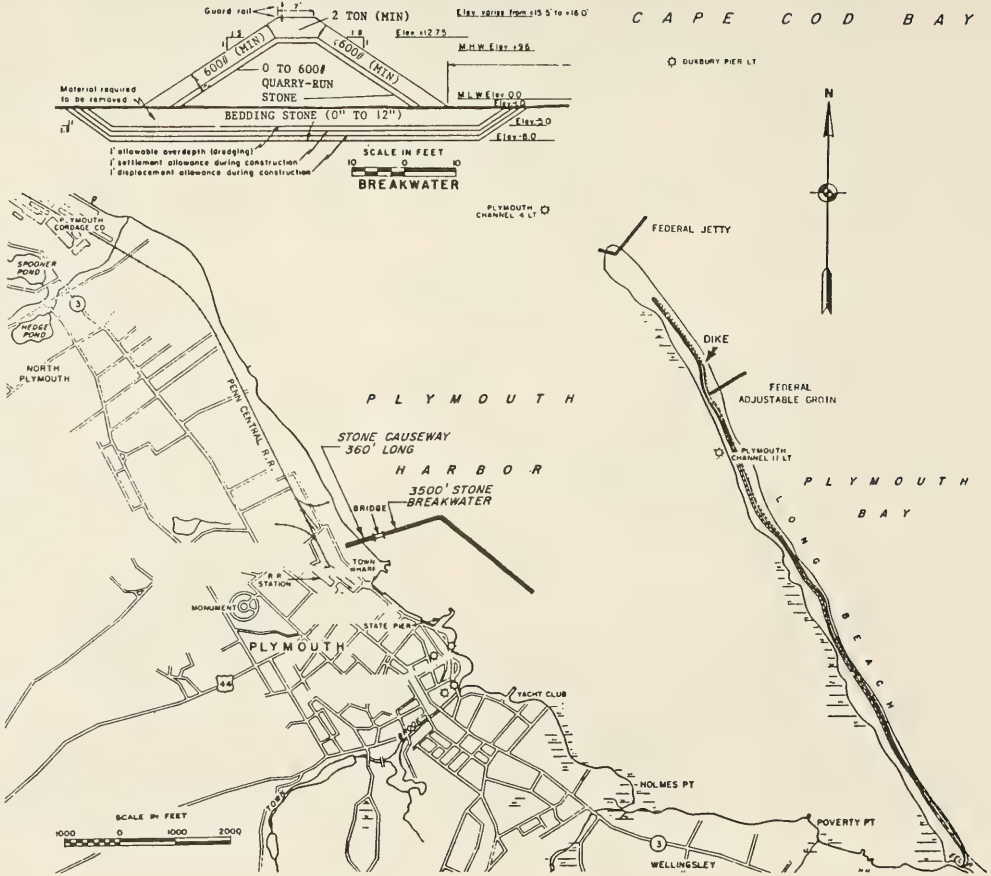


Figure 26. Breakwater at Plymouth Harbor, Mass.

Table 24

Cape Cod Canal Jetties

Cape Cod Canal, Mass.

Date(s)	Construction and Rehabilitation History
1908-1913	Two rubble-mound jetties were constructed by non-Federal interests at Cape Cod Canal's eastern entrance (Figure 27). The north jetty was 3,000 ft long, with a +18 ft mlw crown elevation, a 25-ft crown width, a 1V:1H channel side slope, and a composite seaside slope of 1V:2H and 1V:1H above and below -12 ft mlw, respectively. Stone placed above and below -12 ft mlw weighed approximately 3 to 6 tons and 100 lb to 2 tons, respectively. At the seaward end a concrete cap was placed. The crown width was 30 ft, and the existing bottom elevation was -32 ft mlw. The south jetty appears to have been constructed to a length of 600 ft, a +10 ft mlw crown elevation, a 20-ft crown width, and 1V:1H side slopes. The south jetty armor stone weighed approximately 3 to 5 tons.
1927	The Cape Cod Canal, including the eastern entrance jetties, was purchased by the Federal government.
1962-1963	The seaward 925 ft of the north jetty was rebuilt to +18 ft mlw. Stone placed on the structure weighed a minimum of 6 tons, except on the 125-ft-long head section, where the minimum size was 12 tons. The head section had a 25-ft crown width and a transition in side slopes from 1V:2H to 1V:3H in the seaward direction. A 20-ft crown width and 1V:2H side slopes were specified on the jetty trunk section. Prior to the repairs, typical crown elevations were from +14 to +18 ft mlw on the trunk section and from +7 to +18 ft mlw on the head section. The contract price for placing an estimated 20,000 tons of stone was $260,000.
1967-1974	Inspection reports indicate the north jetty was in good condition, while the south jetty was in poor condition with numerous voids and displaced slope stone along its entire length.
1974	The south jetty was rebuilt to +13 ft mlw. The rebuilt section was 690 ft long and terminated at the jetty's seaward end. Side slopes were 1V:1.5H. A 13-ft crown width and 5- to 7-ton stone were specified on the seaward 200 ft. The remaining section required a 10-ft crown width and 1- to 2.5-ton stone. A 1-ft-thick layer of bedding stone, 0 to 50 lb in size, was placed along the outermost 450 ft of the jetty's seaside toe. Prior to the repairs, crown elevations were typically from +3 to +8 ft mlw. The contract price for placing an estimated 15,500 tons of stone was $224,800.
1977	The jetties were visually inspected. The south jetty was found to be in good condition, while the north jetty needed repairs throughout its entire length.
1986	Recent yearly visual inspections indicated the jetties were in good condition.

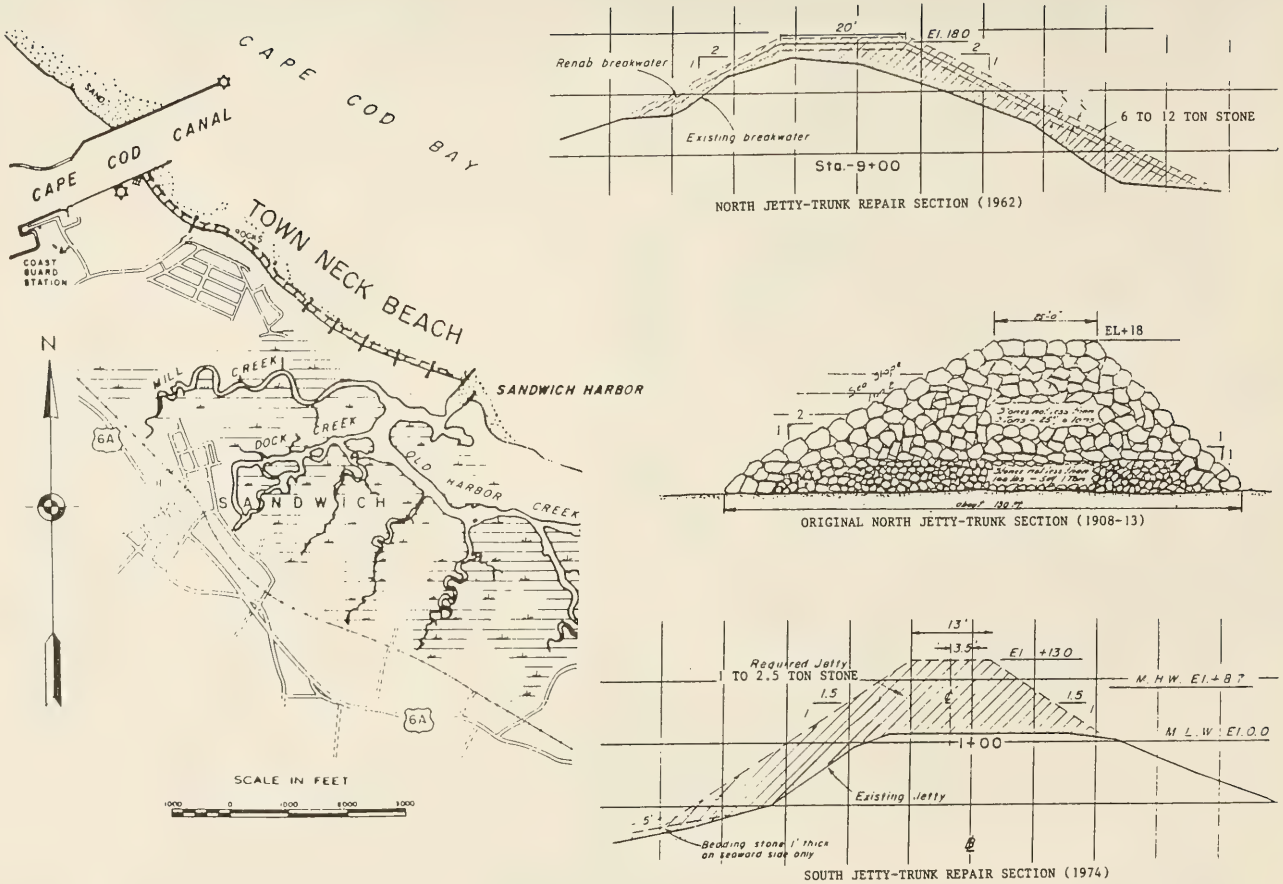


Figure 27. Plan view and typical sections of jetties at Cape Cod Canal, Mass.

Table 25

Provincetown Harbor Breakwater

Provincetown, Mass.

Date(s)	Construction and Rehabilitation History
1970-1972	A 2,500-ft-long rubble-mound breakwater was constructed, providing Provincetown Harbor protection from storm waves (Figure 28, plan view). The breakwater was placed shore parallel, except for a 350-ft-long shoreward hook at its northern end, and located approximately 2,000 ft offshore in water depths of -11 to -20 ft mlw. The design geometry consisted of a +15.5 ft mlw crown elevation, a 10-ft crown width, and 1V:1.5H side slopes. The breakwater heads differed only in having 12-ft crown widths (via 100-ft width transition sections). The 0- to 50-lb bedding stone was placed in a 3- to 4-ft-thick layer and extended 5 to 8 ft beyond the cross-section toe. The core stone and slope stone below -8 ft mlw were 100 to 4,000 lb in size. A double layer of 5- to 8-ton cover stone was placed above -8 ft mlw. The contract cost for placing an estimated 328,000 tons of stone was $3,534,000. The design was based on an 8-ft, 7.3-sec fetch-limited wave height and a maximum tide level of +12.2 ft mlw. Stone size was selected using Hudson's slope stability formula.
1978	The breakwater was found to be in excellent condition during a visual inspection.
1984	Recent yearly visual inspections indicated that the breakwater was in good condition.

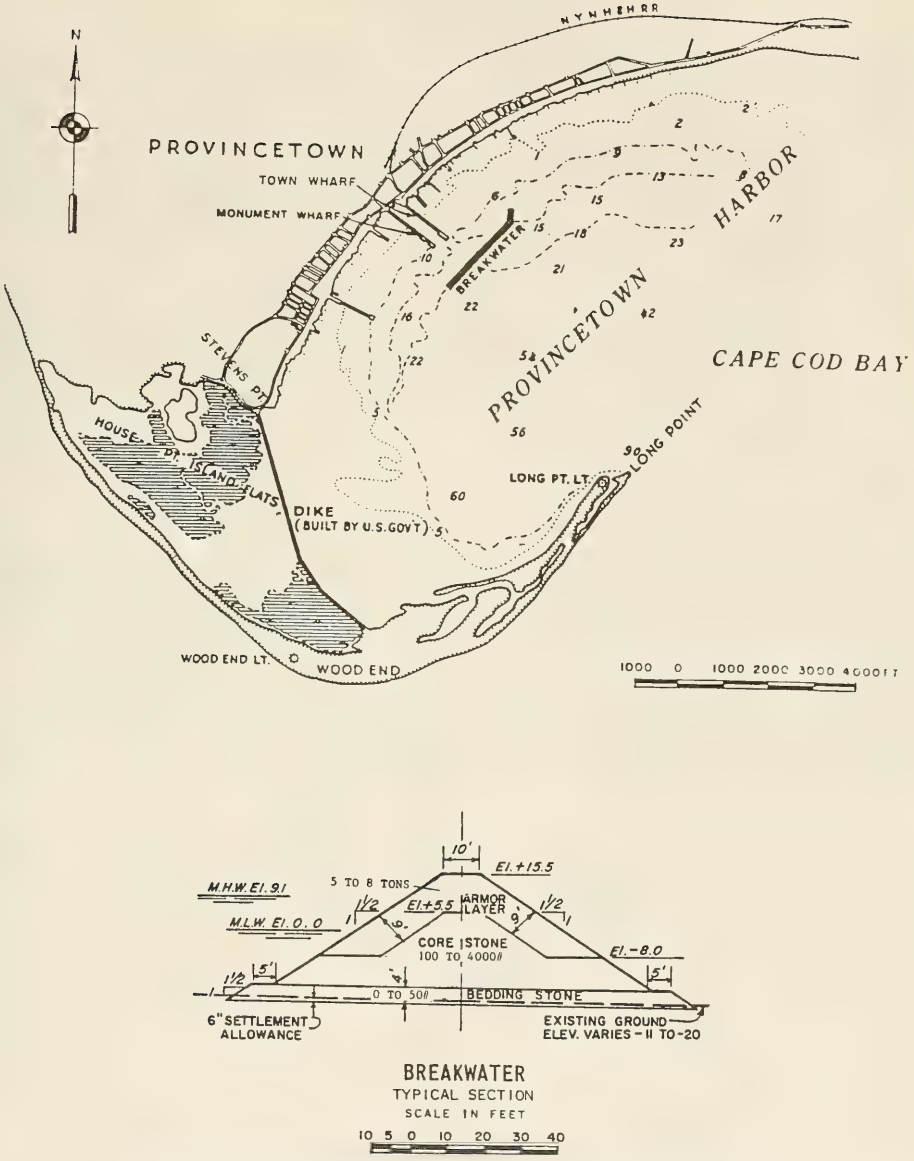


Figure 28. Breakwater at Provincetown Harbor, Mass.

Table 26

Chatham Harbor Jetty

Chatham, Mass.

Date(s)	Construction and Rehabilitation History
1965	As part of improvements at Chatham Harbor, a 200-ft-long rubble-mound jetty was constructed on the west side of the entrance channel (Figure 29). The armor stone was approximately 0.5 to 2 tons in size, and the core stone varied from 0 to 500 lb (cross-section details not known). The cost for placing an estimated 1,375 tons of stone was $13,750.
1967	The jetty was extended approximately 300 ft landward via rubble-mound and stone revetment. Erosion of the adjacent shoreline had resulted in flanking of the jetty's inshore end. The rubble-mound section was built using 0.5- to 2-ton cover stone and 0- to 50-lb core stone. The contract cost for placing 945 tons of stone in the extension was $12,950.
1968-1977	Visual inspections indicated the jetty was in excellent condition.
1986	The present condition of the jetty is not known.

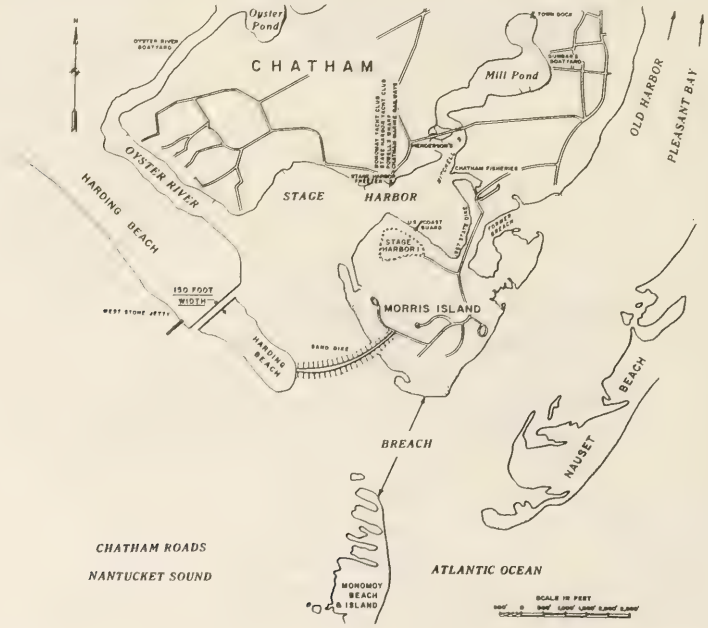


Figure 29. Plan view of Chatham Harbor Jetty, Chatham, Mass.

Table 27

Nantucket Harbor Jetties

Nantucket Island, Mass.

Date(s)	Construction and Rehabilitation History
1881-1907	The east and west rubble-mound jetties were constructed to lengths of 6,987 and 4,955 ft, respectively. The jetties converged to a distance of approximately 1,000 ft, with the east jetty extending 800 ft seaward of the west jetty (Figure 30, plan view). Crown elevations were typically +5 ft mlw, side slopes 1V:1H, and crown widths 4 and 6 ft on the west and east jetties, respectively. Approximately 63,000 and 59,000 tons of stone were used in the east and west jetties, respectively.
1917	The outer end of the east jetty was reconstructed for the purpose of mounting a navigation light. A total of 1,790 tons of stone was used for a total cost of $5,300.
1926	East jetty repairs were made on all but the outer 300 ft of its length. The total repair cost was $41,600.
1936-1937	East jetty repairs were made using 15,900 tons of stone at a total cost of $56,900.
1962-1963	About 4,400 lin ft of the east jetty was rehabilitated. The repair sections were located from 5+50 to 6+00 and from 8+34 to 52+00. The jetty's seaward end was at approximately 52+75. The design crown width and side slopes were 6 ft and 1V:1.5H, respectively. The landward and seaward sections were raised to +5 and +3 ft mlw, respectively. Minimum stone size was 1.5 tons, with 75 percent of the total stone quantity in pieces weighing a minimum of 2 tons. Prior to repairs, the seaward section had typical crown elevations between +1 and -2 ft mlw. The repairs required 15,100 tons of stone for a total cost of $181,000.
1967-1977	Visual inspections indicated the east jetty was in fair condition with some displacement of stone noted. The west jetty was in poor condition, with most of the structure below mhw (+3 ft mlw).
1981	Yearly visual inspections indicated the jetties were in good condition.
1986	Present conditions of the jetties are not known.

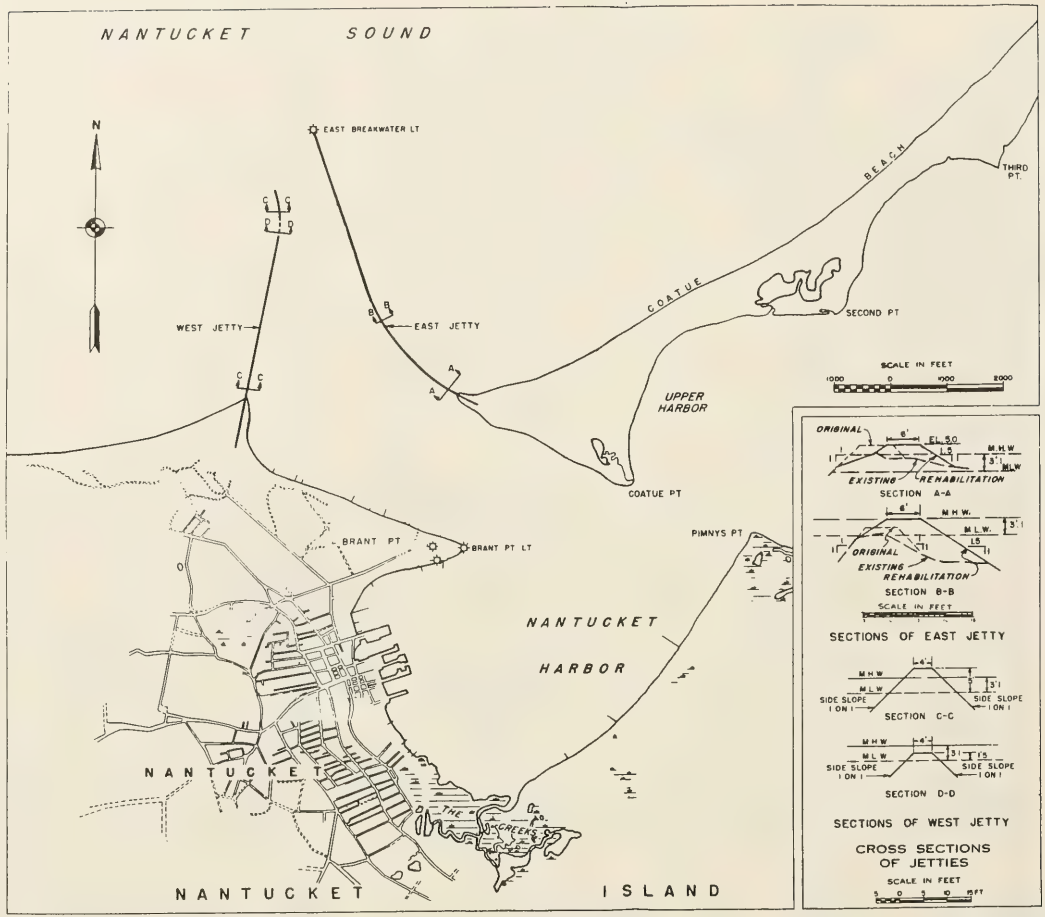


Figure 30. Plan view and typical sections of Nantucket Harbor jetties, Nantucket Island, Mass.

Table 28

Andrews River Jetties

Andrews River, Mass.

Date(s)	Construction and Rehabilitation History
1967	As part of improvements which included a small-boat harbor, a 600-ft-long rubble-mound jetty was constructed on the east side of the Andrews River mouth (Figure 31). The design cross section (from a detailed project report (DPR) dated May 1966) consisted of a +6 ft mlw crown elevation, a 5-ft crown width, and 1V:1.5H side slopes. The section was to be built on a 1-ft-thick blanket of 0- to 50-lb stone, followed by a core of 1- to 300-lb sand tight quarry stone, and covered with 400-lb to 1-ton armor stone. Cover stone at the outer end was 1 to 2 tons. A total of 2,750 tons of stone was placed for a total cost of $23,700.
1973	The 655-ft-long west jetty and 54 ft of wing wall were constructed using a total of 5,280 tons of stone for a total cost of $78,400. The design cross section was probably identical to the east jetty section (based on 1966 DPR). Stone sizes were similar to the east jetty sizes, except that larger 1- to 2-ton stone was not used at the seaward end.
1974	Visual inspection indicated the jetties were in excellent condition.
1981-1986	Yearly visual inspections indicated the jetties were in good condition.

Figure 31. Plan view of Andrews River jetties, Harwich, Mass.

Table 29

Hyannis Harbor Breakwater

Hyannis Harbor, Mass.

Date(s)	Construction and Rehabilitation History
1827-1936	The breakwater (Figure 32, plan view) was constructed between 1827 and 1837 and rebuilt between 1870 and 1882. The inner leg of the breakwater, about 2,250 ft long, was built by the State of Massachusetts. The 1,170-ft-long outer leg of the breakwater was built and maintained by the Federal government. The rebuilt cross-section had a 10-ft crown width at +10 ft mlw and may have been of cut stone construction since the side slopes were nearly vertical. Minor repairs were made in 1936.
1950	The outer 1,170-ft-long leg of the breakwater and adjacent 10 ft of state breakwater were repaired with 1- to 6-ton stone. The repair geometry consisted of a 10-ft crown width at +10 ft mlw and 1V:1H side slopes. A total of 3,224 tons of stone was placed for a cost of $29,200. Prior to the repairs, existing crown elevations varied from +5 to +10 ft mlw. The State portion of the breakwater was considered to be in poor condition.
1961	The outer leg of the breakwater was repaired from 0+00 to 7+80 and 10+75 to 11+15 (breakwater bend at 0+00, seaward end at 11+70). The repair section consisted of an 8-ft crown width at +10 ft mlw, 1V:1.5 side slopes, and 2- to 7-ton armor stone. Before the repairs, crown elevations were from +5 to +10 ft mlw. The repair costs were $129,800 using a total of 13,588 tons of stone.
1966-1974	Inspections indicated the Federal portion of the breakwater was in fair condition.
1982-1986	Yearly visual inspections indicated the breakwater was in good condition.

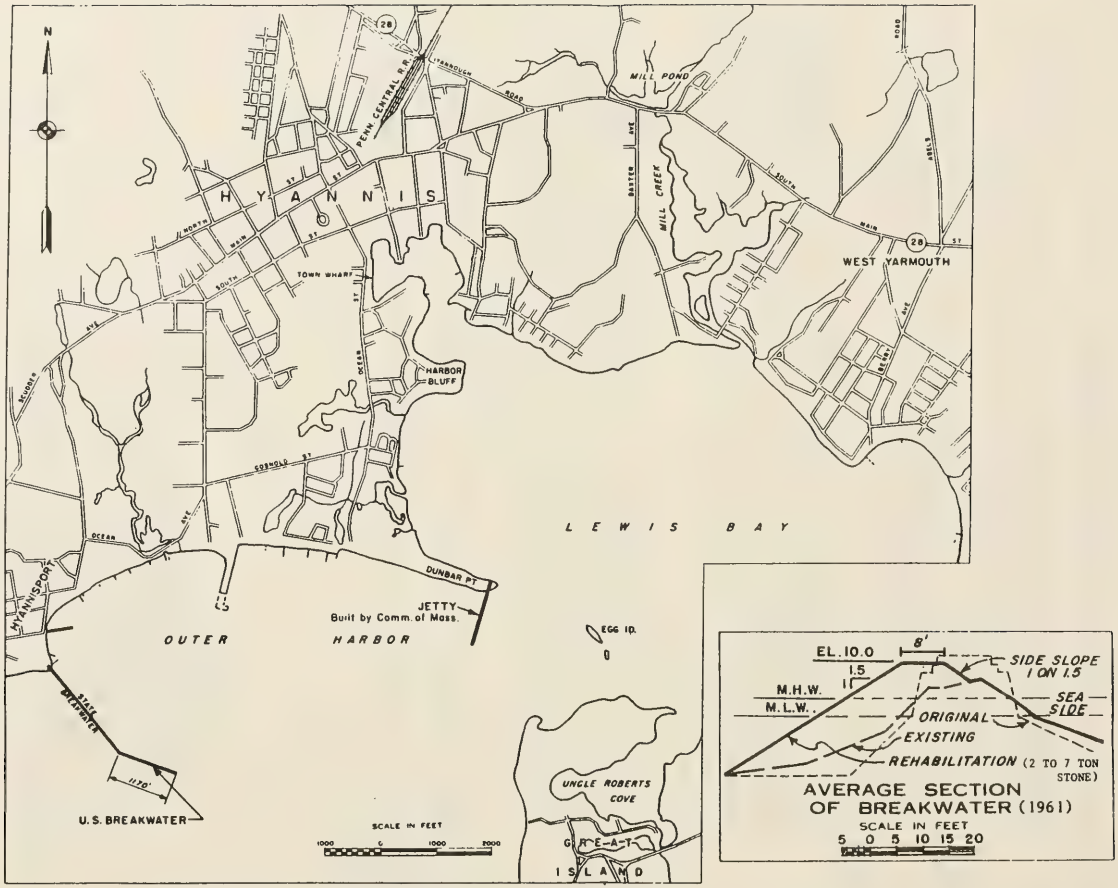


Figure 32. Location map of breakwater at Hyannis Harbor, Mass.

Table 30

Lagoon Pond Jetty

Martha's Vineyard, Mass.

Date(s)	Construction and Rehabilitation History
1935	The State of Massachusetts constructed approximately 450 ft of rubble-mound jetty on the east side of the entrance to Lagoon Pond (Figure 33). It appears that the crown elevation and width were +8 ft mlw and 4 ft, respectively. The crown consisted of 4- by 7- by 2-ft granite blocks, and 1- to 5-ton riprap was used on the side slopes.
1973	As part of navigation improvements, to increase harboring areas for the recreational fleet, the jetty was extended 200 ft seaward, terminating at about the -8 ft mlw contour. The landward side of the existing jetty had accreted sediment and created a fillet out to its seaward end. The plan of improvement called for an 8-ft-deep channel into Lagoon Pond and an extension of the jetty to reduce future channel shoaling. The design section called for a 6-ft crown width at +8 ft mlw and 1V:1.5H side slopes. The seaward end had a 1V:2H side slope. The jetty was built with a 2-ft-thick bedding layer of 1- to 50-lb stone, a sand tight core of 1- to 300-lb core stone, and a 4-ft-thick cover layer of 5- to 6-ton armor stone. The design was based on an 8-ft breaking wave height. The contract cost for placing an estimated 5,700 tons of stone was $98,200.
1974	The jetty and extension were considered to be in excellent condition during a visual inspection.
1982-1986	Yearly visual inspections of the jetty revealed that it was in good condition.

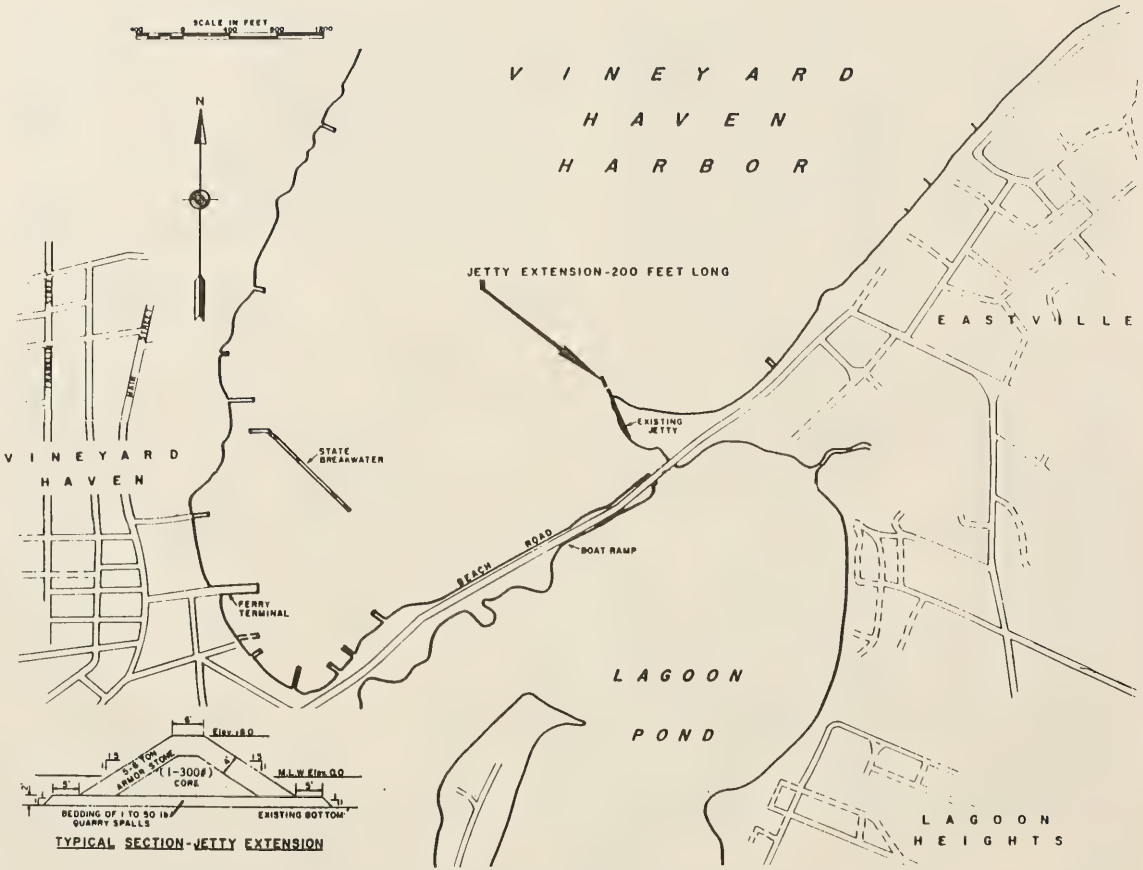


Figure 33. Plan view of Lagoon Pond jetty, Martha's Vineyard, Mass.

Table 31

Menemsha Creek Jetties

Martha's Vineyard, Mass.

Date(s)	Construction and Rehabilitation History
1945	The east and west jetties, approximately 250 and 435 ft long, respectively, were constructed by non-Federal interests prior to 1945 (Figure 34). The project, adopted by the government in 1945, included maintenance of the riprap jetties.
1969	The west jetty was rebuilt by placing approximately 2,100 tons of cover stone and 900 tons of seal stone. The repairs were made over a distance of 435 ft at a contract cost of $67,500. The design section consisted of a +7 ft mlw crown elevation, a 6-ft crown width, and 1V:1.5H side slopes.
1981	The east jetty was rebuilt with 20-to 400-lb core stone and 1- to 3-ton cover stone. The design section had 1V:1.5H side slopes and a 6-ft crown width at +7 ft mlw. The contract price for placing an estimated 2,750 tons of stone was $91,600.
1982-1987	Annual visual inspections of the jetties indicated they were in good condition.

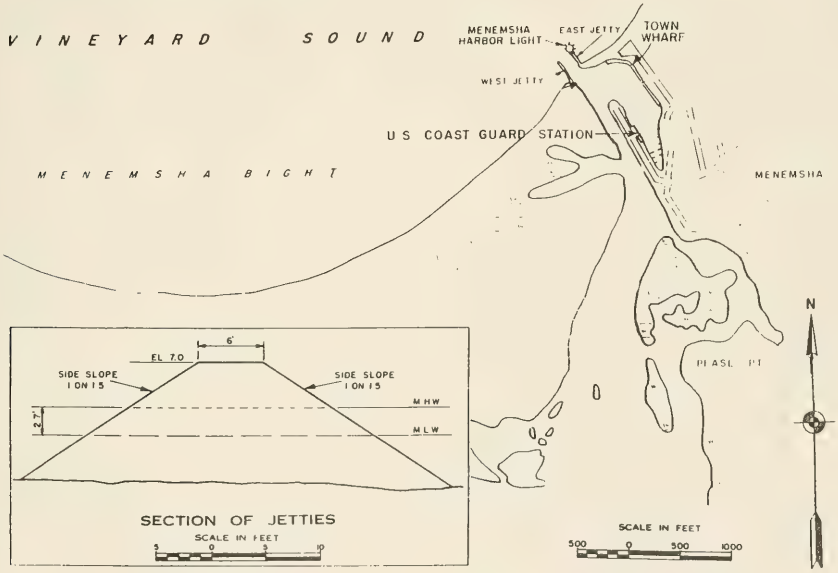


Figure 34. Plan view and typical section of Menemsha Creek jetties, Martha's Vineyard, Mass.

Table 32

Cuttyhunk Harbor Jetties

Cuttyhunk Harbor, Mass.

Date(s)	Construction and Rehabilitation History
1906-1935	During this period the north and south rubble-mound jetties, approximately 520 and 280 ft long, respectively, were constructed and maintained by the State of Massachusetts (Figure 35).
1937-1939	In 1937 the Federal government adopted the Cuttyhunk Harbor Project, which included maintenance of the jetties. In 1939, repairs were made to the north jetty using 500 tons of stone at a cost of $3,600. The repairs restored the crown elevation to +8 ft mlw.
1951	The north jetty was repaired using approximately 1,800 tons of stone at a cost of $14,400. The stone ranged in size from 0.5 to 8 tons and was placed to an elevation of +7 ft mlw, 1V:1.5H side slopes, and a 3- to 5-ft crown width.
1962-1977	Visual inspections indicated the north jetty was in good condition, and the south jetty was in very poor condition. During the early 1960's recommendations were made which included repair of the south jetty, and subsequent repairs were made.
1984-1986	Annual visual inspections indicated the jetties were in good condition.

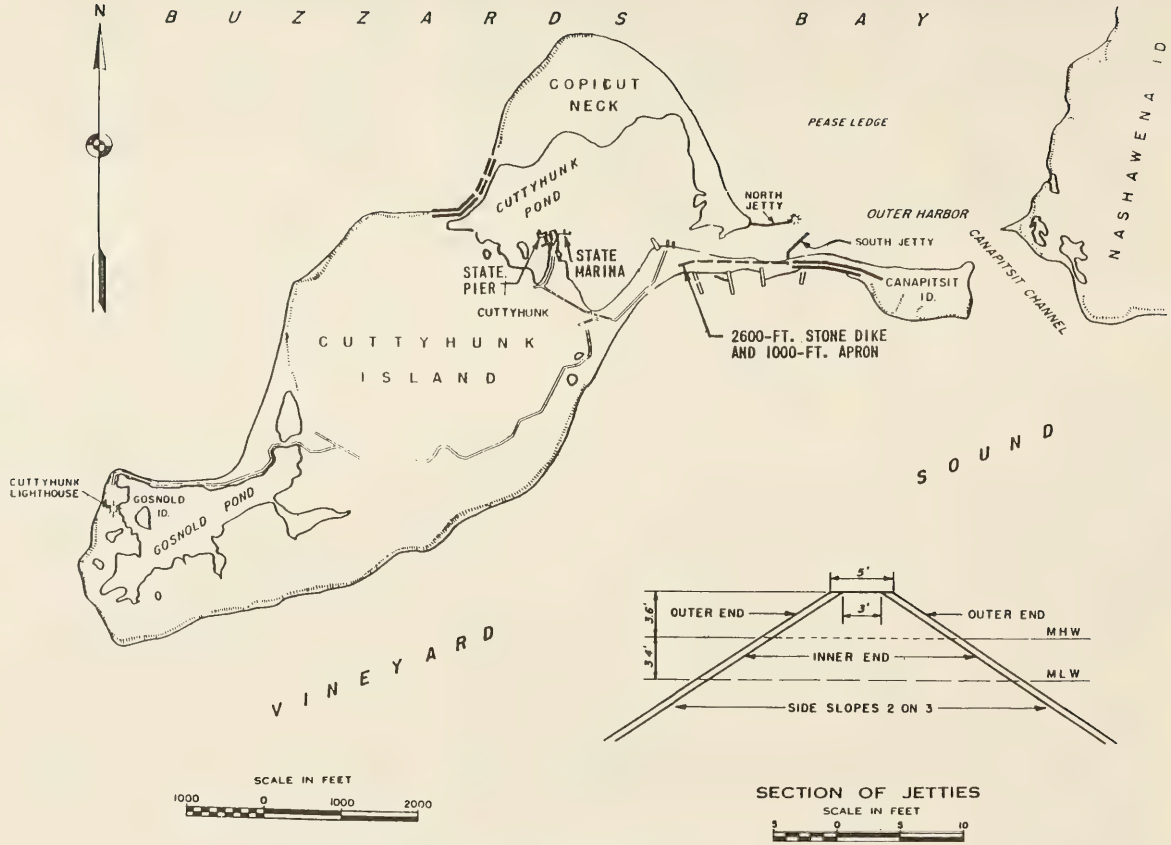


Figure 35. Jetties at Cuttyhunk Harbor, Mass.

Table 33

Sakonnet Harbor Breakwater

Sakonnet Harbor, R.I.

Date(s)	Construction and Rehabilitation History
1836	Two hundred feet of the proposed 400-ft-long rubble-mound breakwater was built for a total cost of $14,700 (Figure 36, present plan view).
1899-1901	The breakwater was extended 200 ft seaward to its authorized length of 400 ft. A total of 18,400 tons of stone was placed in the extension at a total cost of $25,000.
1939	The breakwater was repaired using 1,120 tons of stone at a total cost of $5,800.
1957	The breakwater was extended 400 ft seaward (Figure 37, aerial photograph), and approximately 800 tons of stone were placed at its landward end. The extension and repair sections were constructed with 0.5- to 6-ton stone placed to an elevation of +8 ft mlw, a 15-ft crown width, and slopes of 1V:2H and 1V:1H on the sea and harbor sides, respectively. A 1V:2H side slope was also used on the head semicircle. The extension was made in water depths varying from -15 to -21 ft mlw. The 150-ft landward repair section included the landward 50 ft of breakwater. The contract cost for placing an estimated 30,000 tons of stone was $169,500. The remainder of the breakwater was in good condition with center-line elevations of +7 to +9 ft mlw, typical.
1960	A June topographic survey shows cross sections for the entire breakwater approximately 2 ft above the design cross section used in 1957. The reason for the apparent change in datum could not be found (for present report purposes).
1961	Repairs were made on three sections totaling 86 lin ft, including a 25-ft section at the seaward end and 9- and 52-ft sections located approximately 140 and 430 ft from the seaward end, respectively. The repairs were made with 0.25- to 5-ton stone placed to an elevation of +10 ft mlw, a 15-ft crown width, and slopes of 1V:2H and 1V:1H on the sea and harbor sides, respectively. Except for the outermost 15 ft of repairs, which appears to have subsided prior to June 1960, the repair areas were apparently damaged by storm waves sometime between the June 1960 survey and a visual inspection in February. The damaged areas had typically subsided from 3 to 5 ft. The contract cost for placing an estimated 1,200 tons of stone was $14,400.
1971-1972	Minor harbor-side slope repairs were made near the landward end of the breakwater. The new riprap was placed for a total cost of $1400. The overall condition of the breakwater was good, except for some seaside slope stone slippage.

(Continued)

Figure 36. Plan view and typical section of breakwater at Sakonnet Harbor, R.I.

Figure 37. May 1976 photograph of Sakonnet Harbor, R.I.

Table 33 (Concluded)

Date(s)	Construction and Rehabilitation History
1974	The landward 485 ft and seaward end of the breakwater were repaired using 3- to 5-ton armor stone and resetting existing stone. Landward repairs were mostly along the seaward side. Repair areas were mostly small, isolated areas of displaced stone which were rebuilt to the grade lines of surrounding sections. The total repair cost was $28,850.
1977-1978	Visual inspections indicate the breakwater was in good condition.
1984-1986	Yearly visual inspections of the breakwater indicated it to be in good condition.

Table 34

Bullocks Point Jetty

Bullocks Point Cove, R.I.

Date(s)	Construction and Rehabilitation History
1958	A 1,000-ft-long combination dike and jetty was constructed on the west side of the entrance to Bullocks Point Cove (Figure 38). The rubble-mound structure was constructed to an elevation of +9 ft mlw. The approximately 300-ft-long jetty had a 5-ft crown width, 1V:1.5H side slopes, a sand-tight core of 3-in. to 200-lb stone, and a cover layer of 1- to 6-ton stone. The contract cost for placing an estimated 10,000 tons of stone in the dike and jetty was $54,000.
1965-1977	Visual inspections indicated the dike and jetty were in excellent condition.
1980	An annual visual inspection indicated that the jetty and dike were in good condition.
1986	The present condition of the structure is not known.

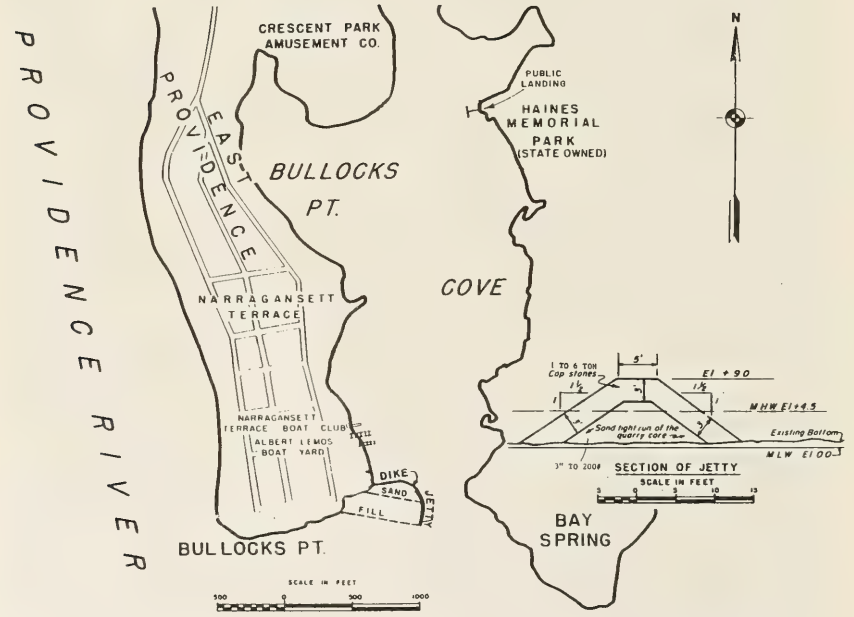


Figure 38. Plan view and design section of jetty at Bullocks Point Cove, R.I.

Table 35

Wickford Harbor Breakwaters

Wickford, Mass.

Date(s)	Construction and Rehabilitation History
1949	The north and south breakwaters were constructed of rubble stone to lengths of 1,130 and 825 ft, respectively (Figure 39). Stone weighing from 0.25- to 4-tons was placed to a crown elevation of +6 ft mlw, a 5-ft crown width, and 1V:1.5H side slopes. Water depths varied from -2 to -10 ft mlw along the breakwaters' center lines. A total of 23,920 tons of stone was placed for a cost of $117,250.
1962-1977	Visual inspections show that both breakwaters have minor displacement of stone. As of 1977, the north and south breakwaters were in good and fair conditions, respectively.
1985	Yearly visual inspection of the breakwaters indicated they were in good condition.

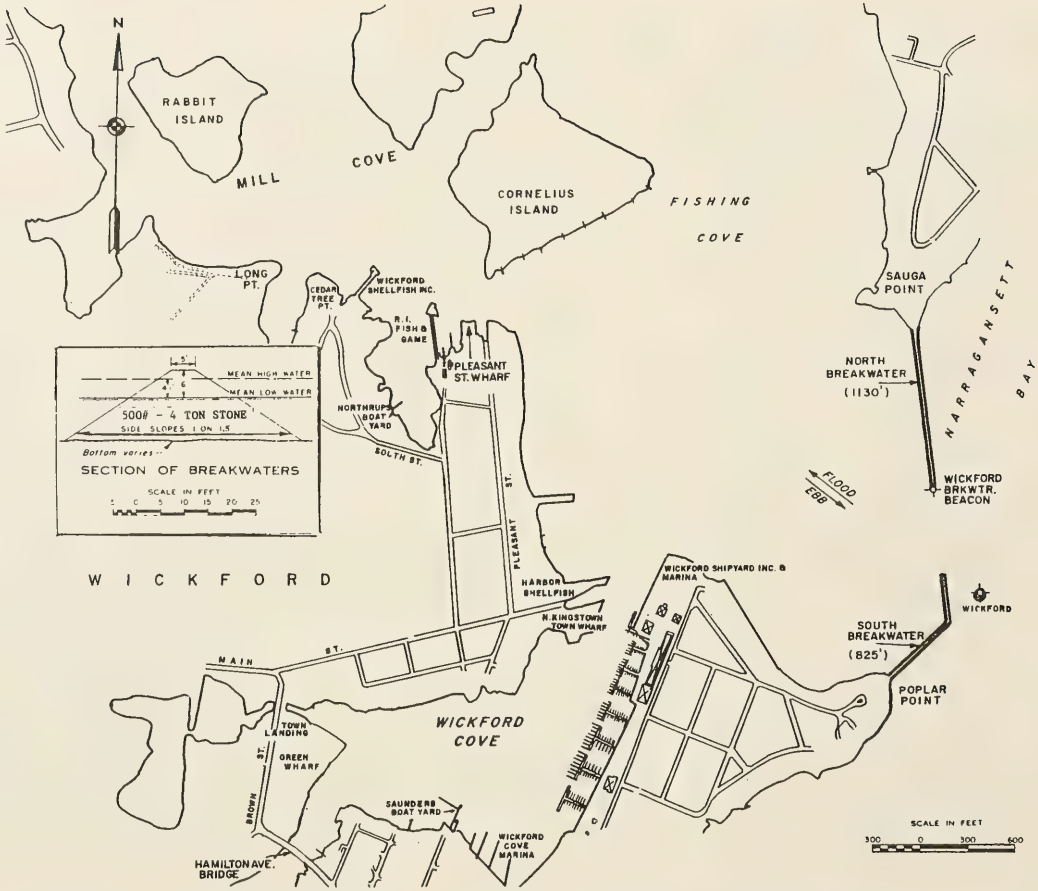


Figure 39. Plan view and typical section of breakwaters at Wickford Harbor, R.I.

Table 36

Point Judith Harbor of Refuge Breakwaters

Point Judith, R.I.

Date(s)	Construction and Rehabilitation History
1891-1914	Three rubble-mound breakwaters were constructed and maintained, providing a Harbor of Refuge at Point Judith (Figure 40). The 6,970-ft-long V-shaped main, 2,240-ft-long east shore arm, and 3,640-ft-long west shore arm breakwaters were built during 1891-99, 1903-09, and 1911-14, respectively. The main breakwater was constructed in water depths from 18 to 34 ft (relative to mlw), and the east and west shore arms were built in depths of up to 26 and 18 ft, respectively. The design cross section for the main and east shore arm breakwaters (Figure 40, inset) had a +10 ft mlw crown elevation, a 20-ft crown width, a 1V:1H harbor side slope, and a composite sea-side slope of 1V:2H and 1V:1H above and below -12 ft mlw, respectively. Subsequent to construction of the main breakwater (date unknown), the design sea-side slope on its west arm was changed to 1V:1.5H. Two design cross sections were used on the west shore arm breakwater (Figure 40, inset). The landward 940 ft had an 8-ft crown width and a +8 ft mlw crown elevation, and the remaining seaward section had a 15-ft crown width and a +10 ft mlw crown elevation. Slopes on both sections were 1V:1H and 1V:2H on the harbor and sea sides, respectively. Core stone (size unknown) was placed to mlw on all sections and facing stone (i.e. cover stone, size unknown) was placed to a thickness of 10 ft on all sections, except on the west shore arm's landward section where the thickness was 8 ft. A total of 1,421,500 tons of stone was placed at total construction costs of $2,149,500. Starting in 1905, repairs were made on previously completed portions of the breakwaters by adding and resetting stone. Most of the repairs were located on the east arm of the main breakwater and the east shore arm breakwater. These areas were exposed to the largest waves generated by several winter storms which occurred during this period. Maintenance costs totaled approximately $190,000 using an additional 36,400 tons of stone.
1927-1929	Repairs were made to the main and east shore arm breakwaters which had numerous deficiencies in cross section due to wave attack. The west shore arm breakwater was in good condition. Approximately 40,000 tons of stone were used for a total cost of $203,400.
1935	The main breakwater was repaired using 6,760 tons of stone for a total cost of $23,000.
1939-1941	Damaged sections of the main and east shore arm breakwaters, sustained during a 1938 hurricane, were repaired using new and reset stone. A total of 46,700 tons of new stone and 4,980 tons of salvaged stone were placed for a total cost of $253,400.

(Continued)

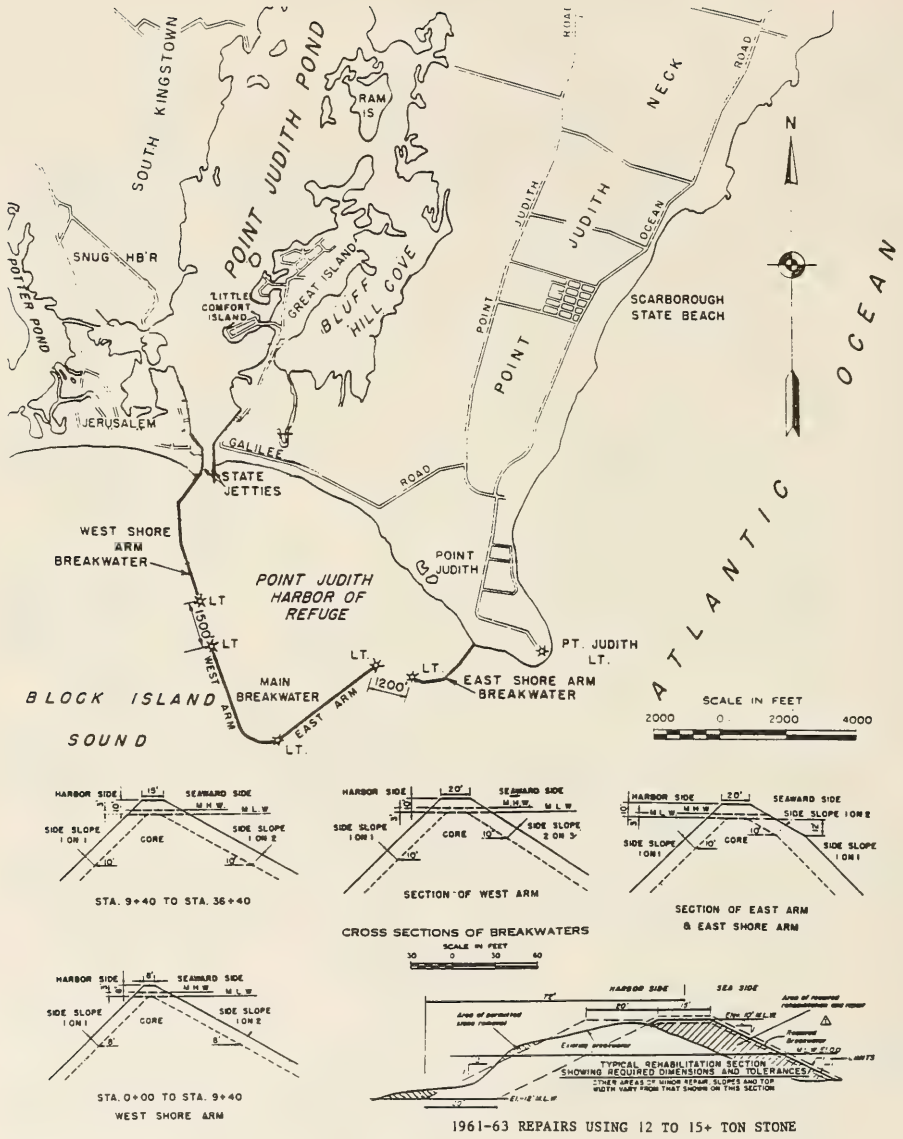


Figure 40. Plan view and typical sections of breakwaters at Point Judith Harbor of Refuge, R.I.

Date(s)	Construction and Rehabilitation History
1950	The breakwaters were repaired; and the landward end of the west shore arm breakwater and the state-owned east jetty, lying on either side of the Point Judith Pond entrance channel, were sand tightened. The sand-tightened sections, 600 and 700 ft long on the jetty and breakwater, respectively, were made by placing a 2-ft-thick layer of 3-in to 500-lb quarry-run stone followed by a 3-ft-thick layer of 1- to 4-ton cover stone on the seaward side slopes. The estimated stone quantity needed for sand tightening was 6,000 tons. The breakwater repairs were made at numerous sections located throughout the east arm of the main breakwater and from 7+50 to 21+25 of the east shore arm breakwater (landward end at 0+00). Approximately 115 lin ft at the seaward end of the original east shore arm was not repaired. Four sections totaling 120 lin ft were repaired on the west shore arm breakwater. The damaged sections were typically 3 to 5 ft below the design crown elevation of +10 ft mlw. The design geometry had 1V:1H harbor side and 1V:2H sea-side slopes, and crown widths of 20, 20, and 15 ft on the east shore arm, main, and west shore arm breakwaters, respectively. The estimated stone quantity needed for repairs was 13,215 tons of 1- to 6-ton stone. Total cost of the improvements was $135,200 using a total of 19,090 tons of stone.
1961-1963	The breakwaters were rehabilitated (Figure 40, inset) using 119,000 tons of stone for a total cost of $1,771,900. The east shore arm was repaired from 9+50 to the reconstructed seaward end at 20+00. The main breakwater was repaired from the seaward end of the west arm at 0+00 to 4+00, at 10+50, and from 31+00 to the seaward end of the east arm at 69+25. Eleven areas, the largest covering 60 lin ft, of the west shore arm were repaired between 12+80 and the seaward end at 36+10. Stone placed on the structures weighed 12 to 15 tons, except for several sections along the east arm where a 15-ton minimum was specified. The repair areas required a +10 ft mlw crown elevation. The east and east shore arm repairs required a 15-ft crown width and 1V:2H side slopes. The west and west shore arm repairs specified 20- and 15-ft crown widths, respectively, with slopes of 1V:1.5H and 1V:1H on their sea and harbor sides, respectively. Prior to rehabilitation, crown elevations within the repair areas were typically from +4 to +9 ft mlw on the east and west arms, 0 to +8 ft mlw on the east shore arm, and +7 to +10 on the west shore arm. Crown elevations outside the repair areas were typically within 2 ft of the +8 and +10 ft mlw design elevations. Overall, the east arm and outer half of the east shore arm were the most deteriorated sections of the breakwaters prior to rehabilitation.
1964-1978	Visual inspections show a gradual deterioration of the main and east shore arm breakwaters. The west shore arm had some displaced stone but was otherwise considered to be in good condition. By 1978, the

(Continued)

Table 36 (Concluded)

Date(s)	Construction and Rehabilitation History
1964-1978 (cont.)	main and east shore arm breakwaters were in poor to very poor condition with numerous deficiencies in cross section, and there were significant amounts of displaced stone on the harbor side of the structures at several locations.
1983-1984	The east shore arm breakwater was repaired, and the main breakwater repairs were started but were not completed due to contractual difficulties. The east shore arm repairs were made using 12- to 15-ton stone and resetting existing stone. The majority of the repairs were located on the seaward half of the breakwater from 10+50 to 20+30. The breakwater was rebuilt to a +10 ft mlw crown elevation, a 20-ft crown width, and slopes of 1V:2H and 1V:1H on the sea side and harbor side, respectively. The cost of repairs was $702,500 for 20,275 tons of new stone and $81,870 for resetting existing stone. The incomplete main breakwater repairs were identical to the east shore arm repairs in stone weight and cross section geometry, except for the side slopes which were 1V:1.5H from 0+00 to 20+34 and 1V:2H from 20+34 to 67+25. The contract, awarded in the amount of $2,275,000, called for placing 57,600 tons of stone and resetting existing stone.

Table 37

Block Island Harbor of Refuge Breakwaters

Block Island, R.I.

Date(s)	Construction and Rehabilitation History
1870-1894	The east and west rubble-mound breakwaters were constructed to lengths of 1,950 and 1,100 ft, respectively (Figure 41, plan view). The east breakwater was built to +10.9 ft mlw with an 11-ft top width, and the west breakwater was built to +8.9 ft mlw with a 20-ft crest width. The sea and harbor side slopes on both structures were 1V:1.5H and 1V:1H, respectively. A total of 107,400 tons of stone was used in constructing the east breakwater, and at least 18,400 tons of stone were used on the west breakwater. In 1890 minor repairs were made to the east breakwater using 420 tons of stone.
1903-1906	The east breakwater was repaired using a total of 19,970 tons of stone at a total cost of $42,900.
1914-1916	Repairs were made at the landward and seaward ends of the east breakwater using a total of 5,930 tons of stone.
1939	Repairs were made to the east breakwater using 3,360 tons of stone for a total cost of $21,000.
1950	The west breakwater was repaired to its design cross section using 0.25- to 6-ton cover stone and "run of quarry" core stone. Typical crest elevations prior to repairs were from 1.5 to 3.0 ft below the design elevation of +8.9 ft mlw. Total cost of the repair was $127,100 using 12,900 tons of stone.
1955	An 800-ft section of east breakwater was repaired and sand tightened by placing 0.75-in. to 200-lb core stone and 1- to 6-ton cover stone. The stone was placed on the breakwater's seaward side slope beginning at a point opposite the northeast corner of the inner basin and terminating about 750 ft from the structure's seaward end. The cross section had a crown elevation of +11 ft mlw, the crown width extended seaward 25 ft from the existing breakwater center line, and the side slope was 1V:1.5H. A total of 12,000 tons of stone was placed for a total cost of $125,000.
1962-1963	The seaward 842 ft of the east breakwater were repaired using 4- to 8-ton stone. Prior to repair, center-line elevations were from +9 to -2 ft mlw on the seawardmost 200 ft, +9 to +12 ft mlw along the remaining 642 ft of repairs, and +10 to +12 ft mlw landward of the repairs. The repair crown section consisted of a +11 ft mlw crown elevation, an 18-ft crown width, and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively. Most of the stone was placed on the sea-side slope. A total of 11,700 tons of stone was used for a total cost of $138,000.

(Continued)

Table 37 (Concluded)

Date(s)	Construction and Rehabilitation History
1977	Inspections up to this time indicated the west breakwater was in good condition and the east breakwater was in fair to good condition. Repair work was needed on the seaward 150 ft of the east breakwater where settlement and loss of sea-side slope stone had occurred since the 1962-63 repairs. Maintenance was subsequently performed.
1984-1987	Yearly visual inspections indicated the breakwaters were considered to be in good condition.

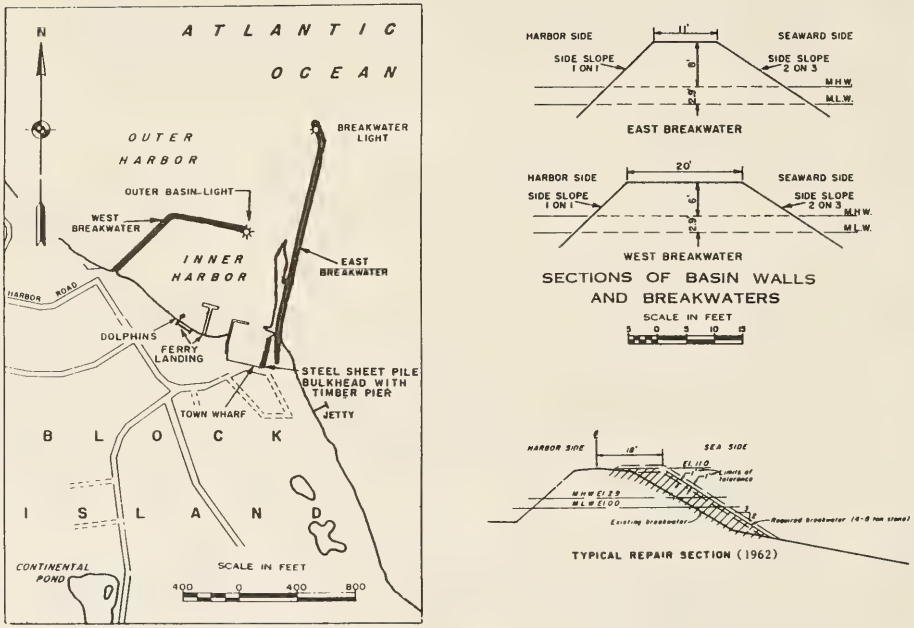


Figure 41. Plan view and typical sections of breakwaters at Block Island Harbor of Refuge, R.I.

Table 38

Great Salt Pond South Jetty

Block Island, R.I.

Date(s)	Construction and Rehabilitation History
1896-1905	A 1,690-ft-long rubble-mound jetty was constructed on the south side of the inlet to Great Salt Pond (Figure 42). The design cross section consisted of a +8 ft mlw crown elevation, a 15-ft crown width, and slopes of 1V:2H and 1V:1H on the sea and channel sides, respectively. The structure's seaward end extended approximately 400 ft beyond the -18 ft mlw contour. A total of 66,860 tons of stone were placed at a cost of $84,900.
1935	Minor repairs were made to the jetty using 1,600 tons of stone for a cost of $5,700.
1965-1977	Visual inspections indicated the jetty was in poor to fair condition and in need of repairs. The outer half of the jetty had many void spaces and areas of displaced stone. Subsequent repair work was performed.
1982	Annual visual inspection indicated the jetty to be in good condition.
1986	The present condition of the jetty is not known.

Figure 42. Plan view and cross section of south jetty at Great Salt Pond, Block Island, R.I.

Table 39

Watch Hill Cove Jetty

Watch Hill Cove, R.I.

	Construction and Rehabilitation History
1948	A 400-ft-long rubble-mound jetty was constructed on the west side of Watch Hill Cove (Figure 43). The jetty was built to an elevation of +8.0 ft mlw, a top width of 5 ft, and 1V:1.5H side slopes. The core consisted of run of quarry stone and cover stone weighed between 600 lb and 2 tons. The cost for placing 456 tons of stone was $3,990.
1974	The jetty was in good condition, with only minor displacement of stone noted along its outer 150 ft.
1982-1986	Annual visual inspections indicated the jetty was in good condition.

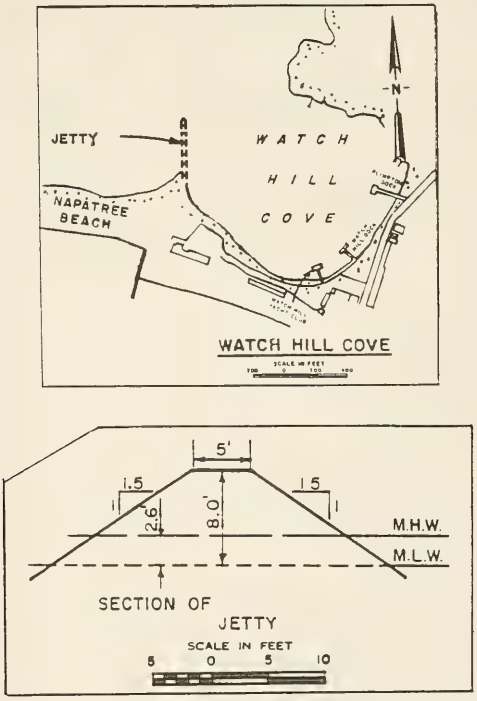


Figure 43. Jetty at Watch Hill Cove, R.I.

Table 40

Stonington Harbor Breakwaters

Stonington Harbor, Conn.

Date(s)	Construction and Rehabilitation History
1875-1894	The west and east breakwaters, 2,025 and 2,900 ft long, respectively, were constructed using total stone quantities of 94,200, and 118,500 tons, respectively (Figure 44). The structures crown widths were 12 ft, and side slopes were 1V:2H and 1V:1H on the sea and harbor sides, respectively. The east and west breakwater crown elevations were +9 and +9.75 ft mlw, respectively. The easternmost 500 ft of the east breakwater was built lower than the remaining breakwater, having a crown elevation of +2.7 ft mlw and an 8-ft crown width. Total construction costs were approximately $210,000.
1958	The breakwaters were repaired using 0.5- to 4-ton stone. Approximately 4000 tons of stone were placed to bring low sections up to their original design geometries (Figure 44, insert). The total repair cost was $38,000.
1962-1977	Visual inspections indicated the breakwaters were in good condition.
1984	Yearly visual inspections indicated that the breakwater was in good condition.

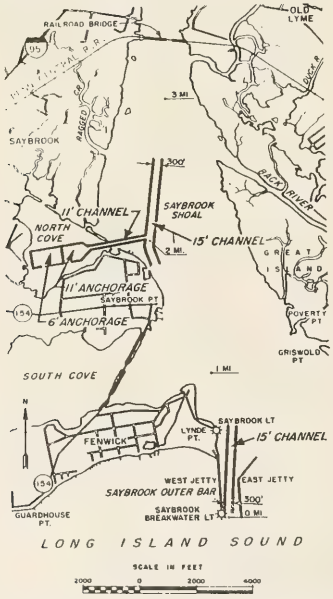
Figure 44. Plan view and cross sections of breakwaters at Stonington Harbor, Conn.

Table 41

Saybrook Jetties

Saybrook, Conn.

Date(s)	Construction and Rehabilitation History
1873-1885	The east and west jetties were constructed at the mouth of the Connecticut River to lengths of 2,300 and 2,250 ft, respectively (Figure 45). The jetties had +5 ft mlw crown elevations, 6-ft crown widths, and 1V:1H side slopes.
1904 1905	The jetties were repaired using 7,650 tons of stone for a total cost of $9,400. The jetties were restored to crown elevations of +5 to +6 ft mlw and crown widths of 6 ft.
1914-1916	The west jetty was repaired and raised to a crown elevation of +8.5 ft mlw. Approximately 16,000 tons of stone were used and 85 cu yd of concrete were placed at the landward end for a total cost of $26,000.
1966-1978	The jetties were considered to be in good condition during visual inspections.
1984	Annual visual inspection of the jetties indicated they were in good condition. The jetties do not appear to have a repair history subsequent to 1916.



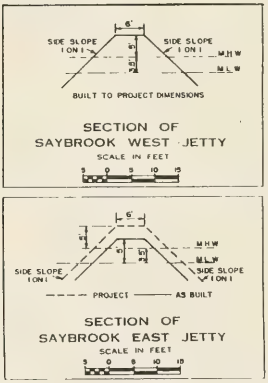


Figure 45. Plan view and design sections of jetties at the mouth of the Connecticut River, Saybrook, Conn.

Table 42

Duck Island Harbor Breakwaters

Duck Island Harbor, Conn.

Date(s)	Construction and Rehabilitation History
1891-1915	Three rubble-mound breakwaters were constructed; one north from Duck Island (1,100 ft long), one west from Duck Island (2,697 ft long), and one south from Stone Island (3,750 ft long) (Figure 46). The breakwaters provide protection for the 16-ft-deep anchorage area behind Duck Island. The Duck Island breakwaters were built to a crown elevation of +9 ft mlw, an 8-ft crown width, and side slopes of 1V:1.5H and 1V:1H on the sea and harbor sides, respectively. The Kelsey (Stone Island) breakwater differed only in using 1V:1.5H side slopes throughout the cross section. The total stone quantities placed in the north, west, and Kelsey breakwaters were 23,100, 139,800, and 244,400 tons, respectively. Minor repairs were made to the west breakwater in 1905, 1909, and 1915 using a total of about 10,000 tons of stone. The Kelsey breakwater was also repaired in 1915 using 460 tons of stone.
1939	Repairs were made to the west and Kelsey breakwaters using 4,500 tons of stone for a total cost of $25,600.
1962-1977	Visual inspections showed the Duck Island breakwaters were in good condition while the Kelsey breakwater was rated from poor to good condition at various times. Subsequent repairs were performed.
1985	Yearly visual inspection of the structures revealed they were in good condition.
1986	Field surveys indicated the breakwaters were found to be in good condition.

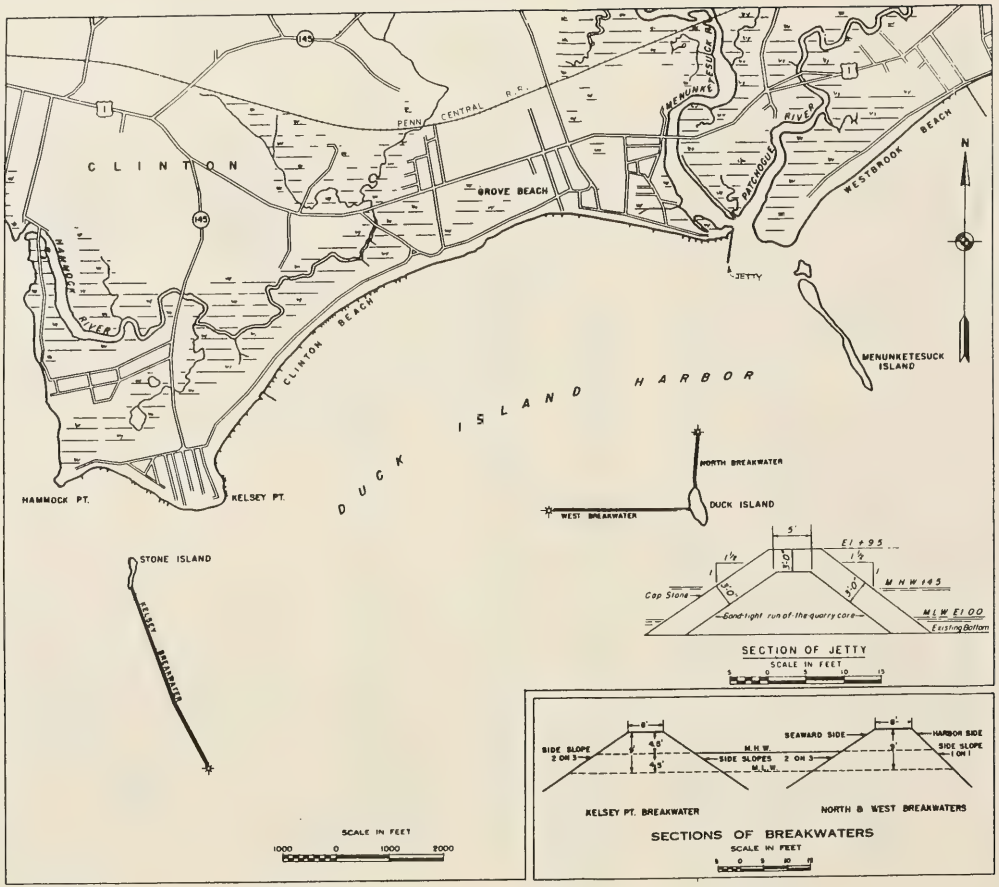


Figure 46. Location map and typical sections of Patchogue River jetty and Duck Island Harbor breakwaters, Westbrook and Clinton, Conn.

Table 43

Patchogue River Jetty

Westbrook, Conn.

Date(s)	Construction and Rehabilitation History
1956	A 600-ft-long rubble-mound jetty was constructed on the west side of the mouth of the Patchogue and Menunketesuck Rivers, providing protection to the 8-ft-deep Patchogue entrance channel (Figure 46). The design section consisted of a +9.5 ft mlw crown elevation, a 7-ft crown width, and 1V:1.5H side slopes. The jetty was built with a sand-tight core of 3-in. to 200-lb stone and covered with a 3-ft-thick layer of 1- to 6-ton stone. The cost for placing 6,470 tons of stone was $45,100.
1962-1977	Visual inspections indicated the jetty was in excellent condition.
1985	Annual visual inspections of the jetty indicated it was in good condition.

Table 44

New Haven Harbor Breakwaters

New Haven, Conn.

Date(s)	Construction and Rehabilitation History
1880-1915	Three rubble-mound breakwaters were constructed as part of the Harbor of Refuge at New Haven (Figure 47). The breakwaters were constructed to a crown elevation of +12 ft mlw, a 12-ft crown width, and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively. The 3,450-ft long east breakwater was built during 1880-90 using 293,800 tons of stone and repaired in 1911 using 2,900 tons of stone. The 4,500-ft-long middle breakwater was built during 1891-96 using 339,000 tons of stone and repaired in 1911 and 1915 using 10,600 and 12,000 tons of stone, respectively. The 4,200-ft-long west breakwater was built during 1896-97 and 1907-11 using 478,100 tons of stone and repaired in 1915 using 14,300 tons of stone. The breakwater's construction costs during this period were approximately $1,120,000.
1935	The breakwaters were repaired using 6,720 tons of stone for a total cost of $18,500.
1960-1974	The breakwaters were considered to be in fair to good condition during several visual inspections taken over this period.
1984	Yearly visual inspection of breakwaters indicated they were in good condition.

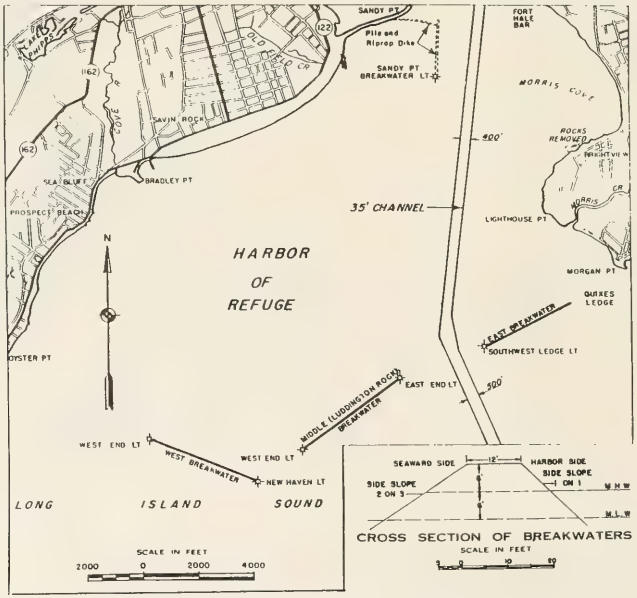


Figure 47. Breakwaters at New Haven Harbor of Refuge, Conn.

Table 45

Milford Harbor Jetties

Milford, Conn.

Date(s)	Construction and Rehabilitation History
1875-1980	To provide protection to Milford Harbor and its entrance channel the Long (east) and Burns Point (west) jetties were constructed to lengths of 510 and 350 ft, respectively, using 4,100 and 900 tons of stone, respectively. The triangular cross section of the west jetty had a crown elevation between +7 and +8 ft mlw and 1V:1H side slopes. The east jetty cross section had a +10.5 ft mlw crown elevation, a 6-ft crown width, and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively.
1948	The jetties were repaired using 1,153 tons of 0.5- to 2-ton stone. The east jetty was repaired to the original cross section, and the west jetty was built up to +7 ft mlw with a 2-ft crown width and 1V:1H side slopes. The repaired lengths of the east and west jetties were 500 and 350 ft, respectively. The total repair cost was $13,700.
1963	The west jetty was repaired using 0.5- to 2-ton stone placed to the 1948 repair cross section. The contract cost for placing an estimated 1,450 tons of stone was $19,400.
1965	The State of Connecticut rebuilt the east jetty and, near its outer end, constructed a 166-ft-long rubble-mound groin. The groin extended seaward in a nearly perpendicular direction from the jetty axis.
1968-1978	Inspections indicated the jetties were in good condition with some minor repairs needed on both.
1984	Annual visual inspections indicated the jetties were in good condition.

Figure 48. Plan view and cross sections of jetties at Milford Harbor, Conn.

Table 46

Housatonic River Breakwater

Stratford, Conn.

Date(s)	Construction and Rehabilitation History
1889-1895	The inner and outer arms of the Housatonic breakwater (Figure 49), 3,250 and 2,570 ft long respectively, were constructed using 12,500 and 44,560 tons of stone, respectively. The inner arm was built to approximately mid-tide level with a crown elevation of +3 ft mlw, a 6-ft crown width, and 1V:1H side slopes. The outer arm was constructed to a crown elevation of +12.7 ft mlw, and 8-ft crown width, and slopes of 1V:1H and 1V:1.5H on the channel and sea sides, respectively. The construction costs totaled approximately $75,000.
1905-1906	Repairs were made to both arms of the breakwater using a total of 3,990 tons of stone.
1911-1916	During this period, the outer breakwater arm was extensively repaired using a total of 16,200 tons of stone. The crest width was increased to 12 ft, and side slopes of 1V:2H were placed on the sea side. In 1914, the inner arm was repaired using 1,000 tons of stone. Total repair costs were $26,200.
1940-1941	The outer arm was repaired using 1,350 tons of stone for a cost of $6,700.
1960-1977	Visual inspections showed the outer arm was in good condition, and only minor repairs were needed at the seaward end. The inner arm was in poor condition and needed repairs throughout its length.
1986	The present condition of the breakwater is not known.

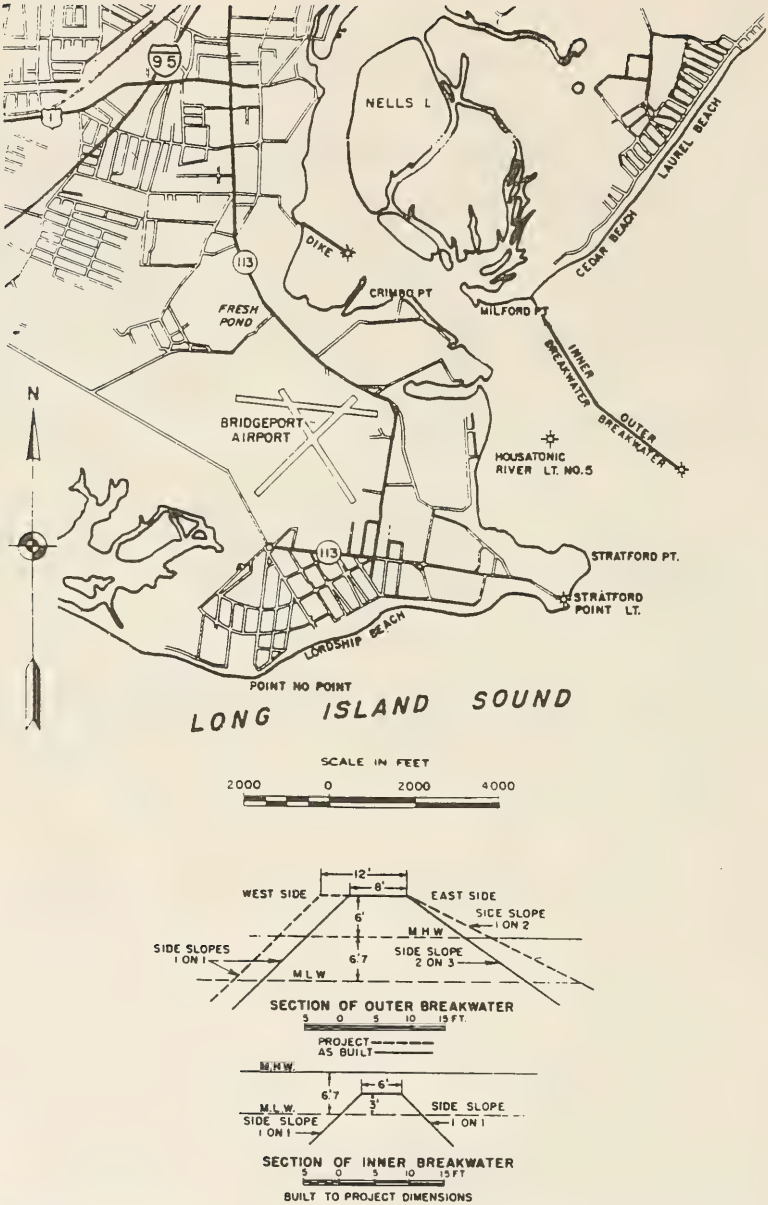


Figure 49. Plan view and cross sections of breakwater at the mouth of the Housatonic River, Conn.

Table 47

Bridgeport Harbor Breakwaters

Bridgeport, Conn.

Date(s)	Construction and Rehabilitation History
1871-1973	The Bridgeport Harbor east breakwater was built to a length of 1,380 ft (Figure 50).
1900	The east breakwater was extended 380 ft using 5,080 tons of stone for a total cost of $10,200.
1907-1908	The east breakwater was extended to a total length of 3,823 ft using 43,560 tons of stone. The completed breakwater cross section consisted of a +9.5 ft mlw crown elevation, an 8-ft crown width, and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively. Total cost of placing 43,560 tons of stone in the extension was $51,000.
1908-1909	The west breakwater was constructed to a length of 2,110 ft using 39,290 tons of stone for a total cost of $46,000. The design section was identical to that of the east breakwater, except for the crown width which was 6 ft.
1935	The breakwaters were repaired for a total cost of $12,500. Stone quantities placed on the east and west breakwaters were 3,300 and 1,170 tons, respectively.
1941	The east breakwater was repaired using 2,650 tons of stone for a total cost of $13,000.
1960-1978	Several visual inspections were made, and the breakwaters were generally in good condition. By 1978 the inspectors recommended the structures be considered for future maintenance.
1986	Present conditions of the breakwaters are not known.

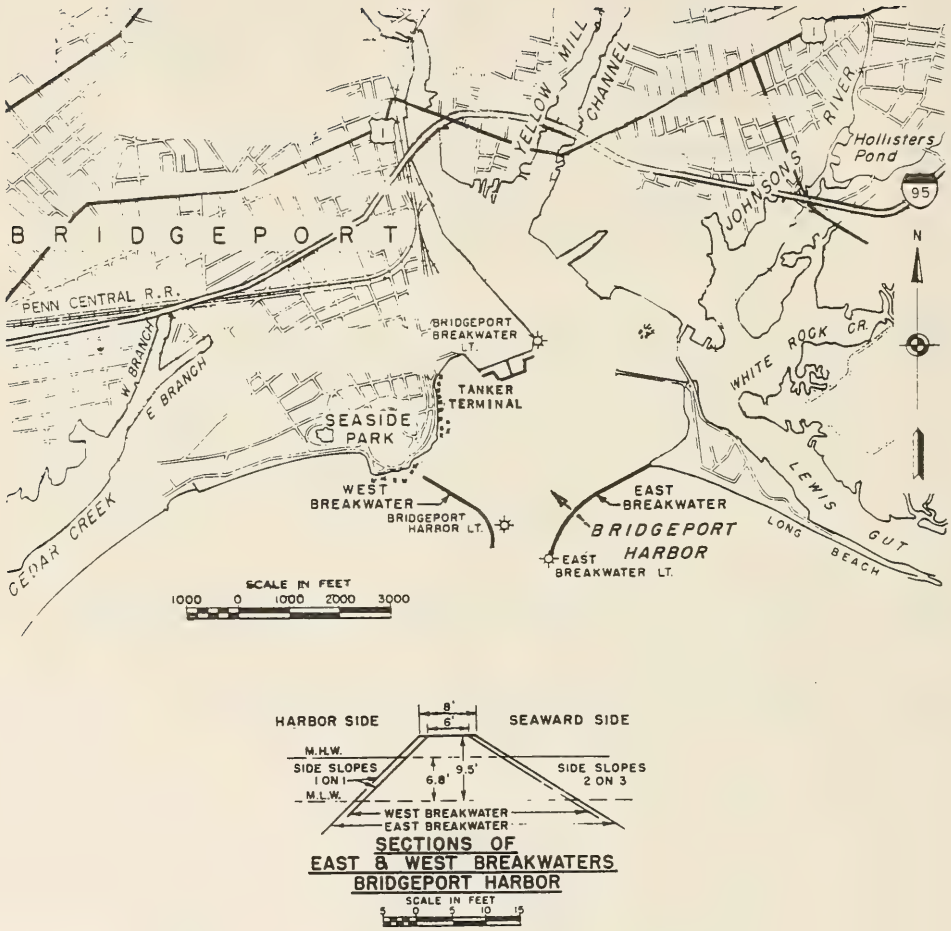


Figure 50. Breakwaters at Bridgeport Harbor, Conn.

Table 48

Jennings Beach and Ash Creek Jetty

Fairfield, Conn.

Date(s)	Construction and Rehabilitation History
1951	An 800-ft-long sand-tight jetty was constructed on the west side (Jennings Beach) of the mouth of Ash Creek (Figure 50). The jetty cross section consisted of a +9 ft mlw crown elevation, a 5-ft crown width, and side slopes of 1V:1.5H. The jetty had a run of quarry core and a 3-ft-thick double layer of cover stone (size not known). The jetty was built by local interests who were reimbursed one-third the first cost of construction by the Federal government.
1986	The jetty has no known repair history, and its present condition is not known.

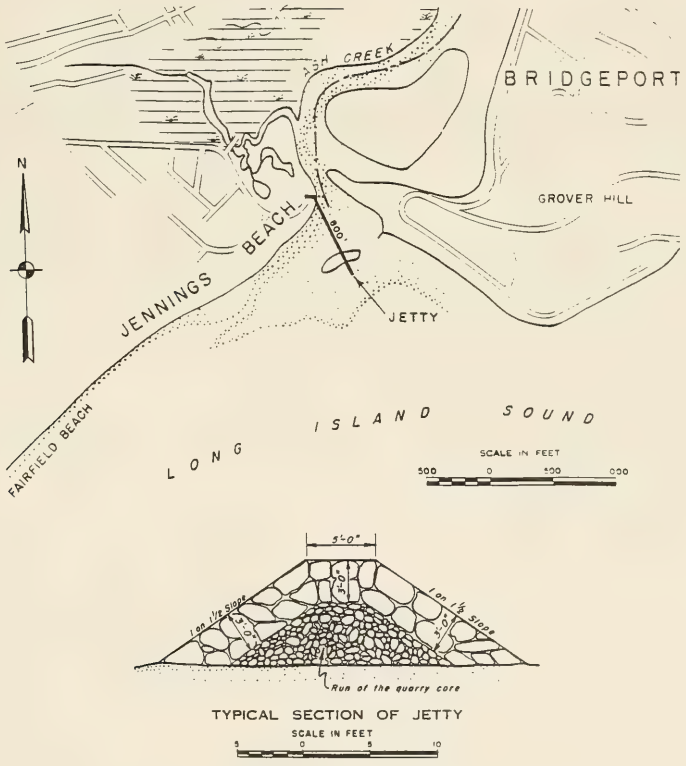


Figure 51. Plan view and cross section of jetty at Jennings Beach and Ash Creek, Conn.

Table 49

Southport Harbor Breakwater

Southport, Conn.

Date(s)	Construction and Rehabilitation History
1838	A 1,320-ft-long rubble-mound breakwater was constructed on the east side of the Southport Harbor entrance channel (Figure 52). It appears that the stone construction was tightly interlocked since the sea and harbor side slopes were approximately 2V:1H and 4V:1H, respectively. The crown elevation and width were +8.5 ft mlw and 8 ft, respectively.
1975-1976	The breakwater crown was capped with 386 cu yd of concrete, and a total of 183 lin ft of the structure was raised using 184 cu yd of rubble stone. The capping, 5 ft wide and 2 ft thick in cross section, raised the crown elevation to +10.5 ft mlw (Figure 52, inset).
1903	Minor breakwater repairs were made at a cost of $150.
1948	Four damaged sections of the breakwater were repaired by placing concrete to restore them to a +10.5 ft mlw crown elevation, a 5-ft crown width, and the existing side slopes of adjacent sections. Approximately 22 cu yd of concrete were used for a total cost of $1,140.
1958	The breakwater was repaired using 0.5- to 3-ton stone and resetting some existing stone. The stone was placed to a crown elevation of +11 ft mlw, a 5-ft crown width, and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively. A total of 3,500 tons of stone were placed for a total cost of $45,350.
1960-1978	During this period, several visual inspections showed the breakwater was in very good condition.
1982	Annual visual inspection of the breakwater indicated it was in good condition.

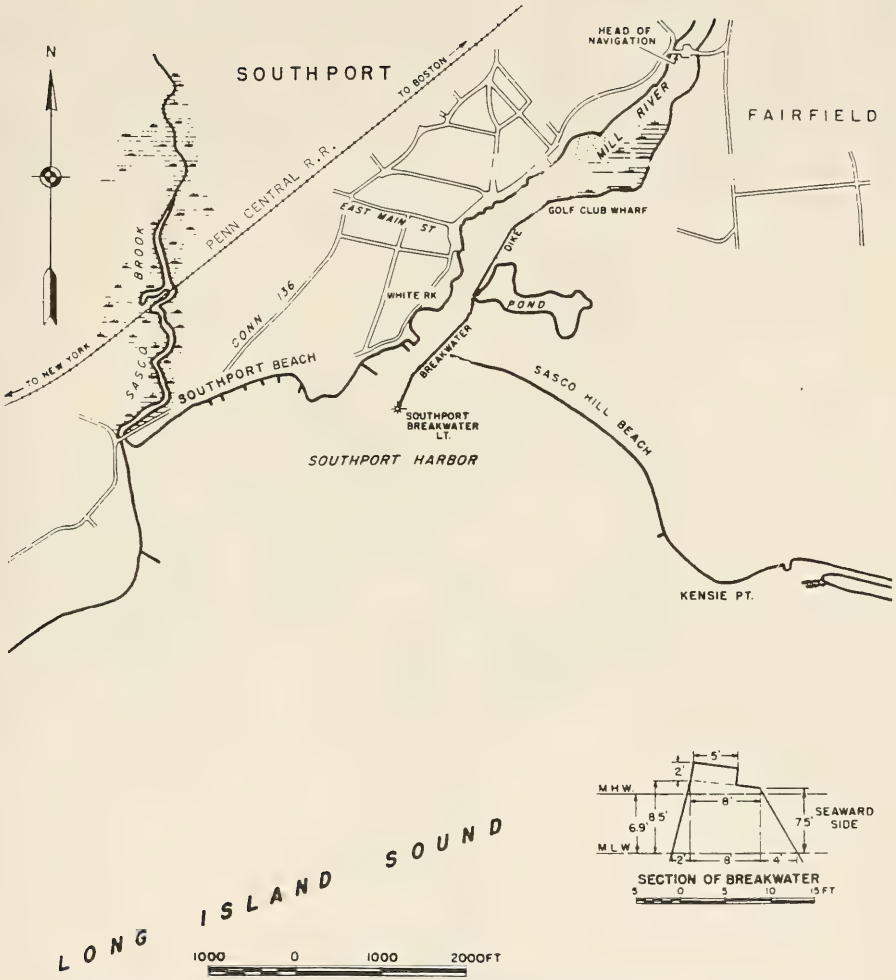


Figure 52. Location map of breakwater at Southport Harbor, Conn.

Table 50

Saugatuck River Breakwater

Saugatuck, Conn.

Date(s)	Construction and Rehabilitation History
1896	A 600-ft-long rubble-mound breakwater was constructed on the east side of the Saugatuck River's mouth (Figure 53). The crown elevation and width were +11 ft mlw and 10 ft, respectively.
1986	The breakwater has no known repair history, and its present condition is unknown.

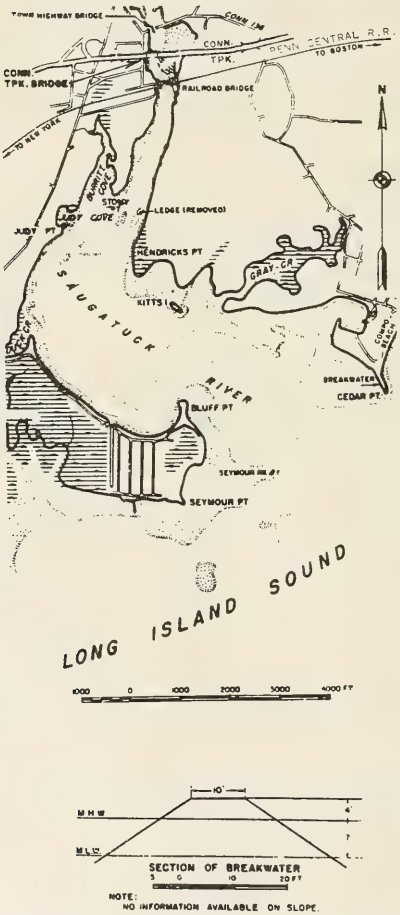


Figure 53. Cedar Point breakwater, mouth of the Saugatuck River, Conn.

Table 51

Cove Island Jetty

Stamford, Conn.

Date(s)	Construction and Rehabilitation History
1958	A 400-ft-long jetty was constructed on the east side of Cove Island (Figure 54). The jetty consisted of a +10 ft crown elevation, a 5-ft crown width, 1V:1.5H side slopes, a sand-tight run of quarry core, and a 3-ft-thick double layer of cover stone. The State of Connecticut, which constructed the jetty, was reimbursed by the Federal government for one-third of the project cost.
1986	The jetty has no known repair history, and its present condition is unknown.

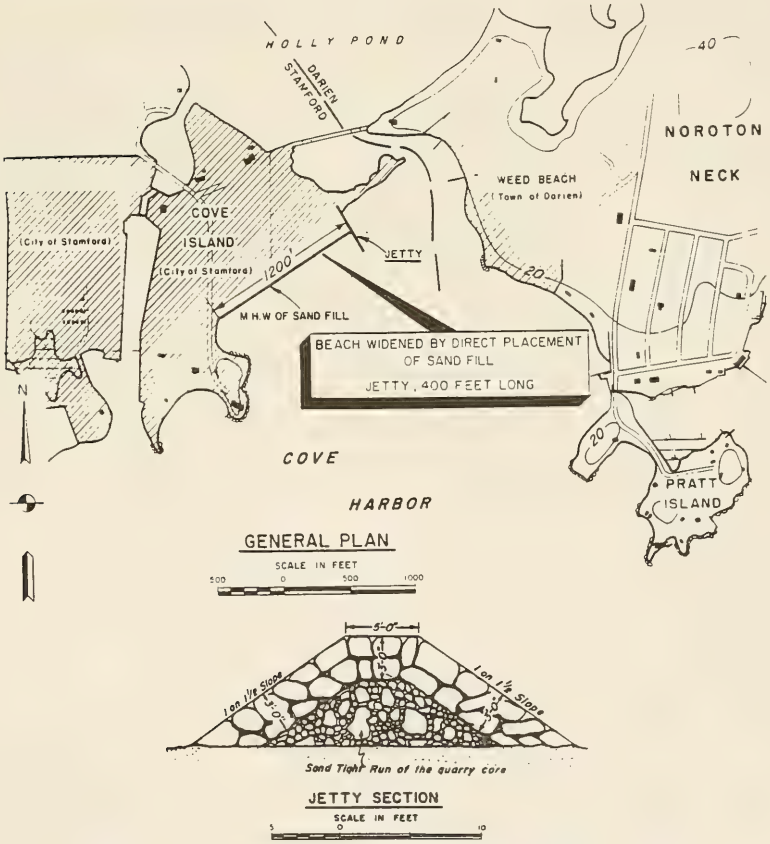


Figure 54. Cove Harbor Jetty, Cove Island, Conn.

Table 52

Stamford Harbor Breakwaters

Stamford, Conn.

Date(s)	Construction and Rehabilitation History
1940-1941	The east and west breakwaters (Figure 55) were constructed to lengths of 1,200 and 2,900 ft, respectively, using 40,100 and 118,100 tons of stone, respectively. The cross section had a maximum crown elevation of +12 ft mlw, a 10-ft crown width at +10.4 ft mlw, and slopes of 1V:1H and 1V:1.5H on the harbor and sea sides, respectively. The total construction cost was $398,900.
1960-1977	Visual inspections indicate the breakwaters were in fair to good condition.
1986	Present conditions of the breakwaters are not known.

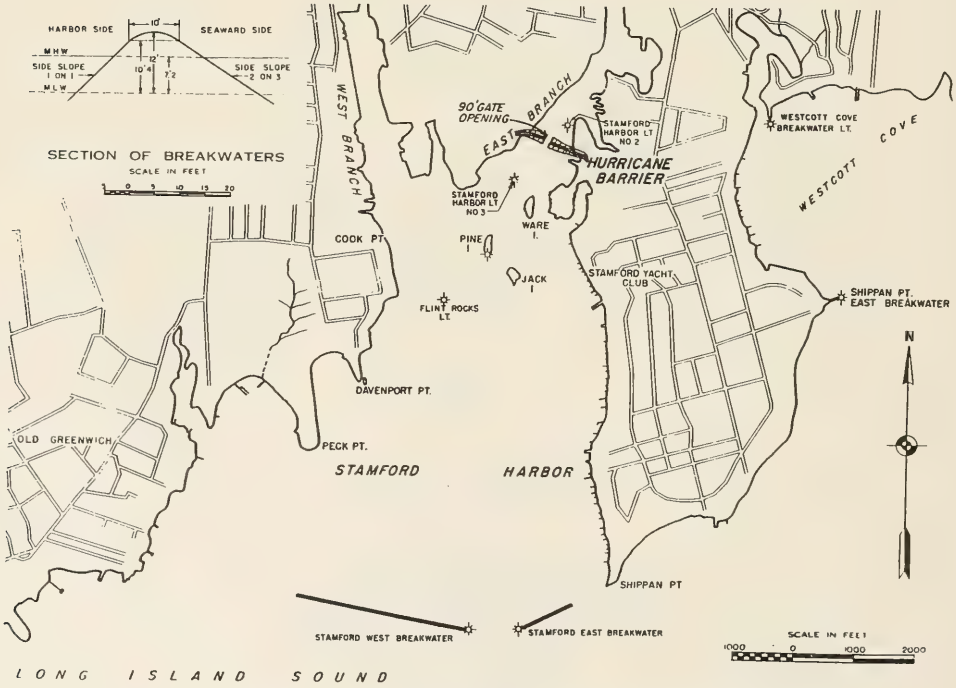


Figure 55. Plan view of breakwaters at Stamford Harbor, Conn.